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NEW ZEALAND JOURNAL OF SCIENCE AND TECHNOLOGY

VOLUME 36

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NEW ZEALAND
JOURNAL OF SCIENCE
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DIRECT EFFECTS OF CLIMATE ON CATTLE

I. SOME OBSERVATIONS ON THE SKIN TEMPERATURE, BODY TEMPERATURE, RESPIRATION RATE AND PULSE RATE OF DAIRY STOCK UNDER NORMAL TEMPERATURE CONDITIONS

By M. R. Patchell, The Dairy Research Institute (N.Z.), Palmerston North

(Received for publication, 9 February 1954)

Summary

Six pairs of identical twin heifers were used to study the variation in skin temperature, body temperature, respiration rate and pulse rate over an air temperature range of 36–67° F. Observations were made on three days per fortnight over a period of three months in the late autumn of 1951. Four sets of readings were made on the group of animals each day. The results were analysed statistically in various ways.

The only direct effect of climate observed was with respiration rates and skin temperatures. Members of a set of twins tend to have characteristic respiration and pulse rates and it was evident that hot conditions caused respiration rates to increase in all animals. Skin temperature did not differ significantly from animal to animal, but hot sunny conditions caused a rise in skin temperature. A difference between animals in body temperature was found, but it is believed that this difference was largely due to the effect of pregnancy rather than to any direct climatic influence. The significant difference found between days in pulse rates is also believed to be due to the effect of pregnancy.

Introduction

In recent years increasing attention has been focussed on the direct effect of climate on animals. Workers in South Africa, U.S.A. and India have reported deterioration and even degeneration of European cattle breeds imported into areas where high air temperature and high solar radiation prevail. In many temperate countries cattle are housed for varying periods of the year, usually as a protection against cold weather, though in some areas as a protection against hot conditions. However, although in some countries standards are laid down regarding optimum ventilation of cattle byres, these are largely empirical. An essential step to the design of more efficient housing is an expansion of fundamental knowledge about heat regulation in cattle. But perhaps the most important aspect of the study of environmental physiology

of cattle is its application to breeding problems in the tropics. There is a great need for guidance under tropical conditions. In the past the tendency has been to import cattle from one area to another in the hope of improving productivity without any prior knowledge of the physiological response of the imported breed to the new environment. Attempts in the past to improve production in the tropics have involved importation of improved British breeds and crossing with native stock. Crossbreds were often an improvement, but degeneration or reversion took place in subsequent generations. This but illustrates the lack of knowledge on the fundamental mechanisms involved. Before any worthwhile breeding plan can be evolved a great deal of fundamental research is required on the regulation of heat loss in cattle.

Information on the body temperature, respiration rate, pulse rate and skin temperature of New Zealand cattle is limited. In the trial described in this paper, the variation in these four measurements under normal conditions was observed. Before trials can be planned to study how production is related directly to the climatic thermal elements, it is necessary to know what is the best time to measure, how to measure and how to interpret results in the light of factors other than climate affecting the various measurements.

REVIEW OF LITERATURE

Excellent reviews on the subject of heat regulation in cattle have been published by Findlay (1950, 1953). Brody and co-workers (1948, 1949, 1951) in a series of experiments under controlled conditions have shown that in European breeds of cattle, increasing the air temperature above 80° F caused a rise in body temperature and respiration rate, a fall in feed consumption, heat production, pulse rate and milk production. Decreasing the air temperature from 50° F to 4° F resulted in a slight decline in milk production and respiration rate, with an increase in feed consumption, heat production and pulse rate. Brahman cows were not affected by high temperatures up to 95° F, but at 105° F were as much affected by the conditions as were European breeds. Information on water consumption and blood composition changes with variations in temperature have also been published by this team of workers.

EXPERIMENTAL MATERIALS AND METHODS

Six pairs of identical twins, all rising two-year-old Jersey heifers, of varying coat colours were used for the trial. Readings of body temperature, respiration rate, pulse rate and skin temperature, were taken on three days per fortnight over the months of April, May and June in 1951. Towards the end of March and in early April, work was in progress on the usefulness of different types of thermocouples and the best positions on the animals to use for routine skin-temperature work. This is to be described in another paper. However, this work was continued during the first set of three days so that data for skin temperature was not as great as for the other measures recorded.

The stock were handled in weighing yards. Each heifer was placed on a chute and all measurements taken there. First, skin temperature was recorded, body temperature and respiration rate together, and

finally pulse rate. The whole process was repeated on the 12 cows four times each day.

Skin temperature was measured by means of a thermocouple of copper constanton wire arranged on a holder which resembled a hacksaw frame. This frame had a system of pulleys attached to a spring so that the tension on the wire could be altered at will. An area of hair about 1 cm. in diameter was shaved and the junction applied to the position which was halfway between the hip bone and spine on the right hand side of each animal. Three separate readings were taken on the potentiometer and the results averaged. The potentiometer was a portable Tinsley model, and the cold junction contained paraffin oil and a wire plunger which served as a pump to keep the oil well stirred.

Body temperatures were taken with rectal thermometers with a thickened bulb. Six of these were calibrated and found to be accurate to within 0.1° F. Each thermometer was fitted at the end opposite the bulb with a rubber bung and a loop of string. The bung allowed the thermometer to be inserted at a constant depth at each reading and the string facilitated ease of handling and shaking down of the mercury. Each reading was made at a depth of 3 in., the time of insertion was 2–3 minutes, depending on the individual thermometer.

Respiration rates were measured by counting the flank movements with the aid of a stop watch. Three half-minute intervals were taken and the results averaged.

Pulse rates were obtained by observing palpitations of the femoral artery. Three half-minute intervals were again taken.

Air temperature was recorded by means of a mercury Fahrenheit thermometer hung in a screen near the chute where the various measurements were made. The air temperature was noted as each animal came into the chute.

The data was analysed by means of analysis of variance. Each analysis was of the special time-series type as outlined by Wilm (1945). This allows the proper testing of some aspects of the analysis by appropriate error or interaction mean squares, but not of others. Subsequent analysis involved repeatability estimates, correlation, regression and multiple regression analyses.

RESULTS

Routine measurements were made on 15 days spread over three months. Breakdowns and unfavourable weather decreased the data for skin temperature measurements. The data for the other measurements were more extensive.

Table 1 shows the analysis of variance with the degrees of freedom and mean squares given.

TABLE 1. TOTAL ANALYSES OF VARIANCE OF (a) SKIN TEMPERATURE, (b) BODY TEMPERATURE, (c) RESPIRATION RATE, AND (d) PULSE RATE

Source of Variation	Degrees of Freedom				Mean Square and Significance							
					a		b		c		d	
	a	b	c	d	M.S.	F.	M.S.	F.	M.S.	F.	M.S.	F.
B. Animals (A.)	11	11	11	11	4.76	NS	1.90	**	545.54	**	1458.36	**
B. Twin Pair	5	5	5	5	6.34	NS	3.22	NS	1145.47	**	3065.20	**
W. Twin Pair	6	6	6	6	3.45		0.80		45.66		119.34	
B. Days (D.)	6	9	9	9	142.54	**	1.17	**	2992.00	**	768.78	**
D. x A.	66	99	99	99	2.50	**	0.22	**	49.03	**	29.68	**
D. x Twin P.	30	45	45	45	2.17	NS	0.34	**	89.75	**	41.07	**
D. x W.T.P.	36	54	54	54	2.77		0.11		15.09		20.16	
B. Readings (R.)	3	3	3	3	87.62	**	7.48	**	367.00	**	168.34	**
R. x A.	33	33	33	33	1.49	NS	0.04	NS	25.63	NS	13.27	*
R. x B.T.P.	15	15	15	15	2.35	**	0.08	**	42.87	*	18.13	NS
R. x W.T.P.	18	18	18	18	0.78		0.01		11.27		9.22	
R. x Days	18	27	27	27	7.40	**	0.18	**	305.11	**	53.56	**
D. x A. x R.	198	297	297	297	1.41		0.05		30.11		8.37	
Total	335	479	479	479								

NS = Not significant

** = Significant at 1% level

* = Significant at 5% level

Table 2 shows the range, mean, standard derivation (derived from the error variances of the appropriate analyses) and coefficient of variation for each of the four measures.

TABLE 2. RANGE, MEAN, STANDARD DEVIATION AND COEFFICIENT OF VARIATION FOR (a) SKIN TEMPERATURE, (b) BODY TEMPERATURE, (c) RESPIRATION RATE, AND (d) PULSE RATE

	(a) Skin Temperature	(b) Body Temperature	(c) Respiration Rate	(d) Pulse Rate Beats/Min.
Range	80.0–100.1°F	100.6–103.8°F	18–75 Resp./Min.	50–92
Mean	93.80°F	101.8°F	34.26	70.23
s	1.18	.22	5.48	2.89
C	1.26	.22%	15.99%	4.12%

Air temperature conditions for each set of 3-day recordings are shown in Table 3.

TABLE 3. AIR TEMPERATURE CONDITIONS DURING THE TRIAL

Day	Set	Air Temperature Range (°F.)
1, 2, 3	1	57.1—64.8
4, 5, 6	2	57.0—67.2
7, 8, 9	3	51.3—62.3
10, 11, 12	4	36.0—58.0
13, 14, 15	5	46.0—58.4

Average readings at corresponding air temperatures are shown in Table 4.

From the analyses of variance various components of variance were derived to show what proportion of the total variance was associated with any given source of variation. These are shown in Table 5.

Correlation Analysis

Correlations were derived for all possible combinations of the five variables, working on a within-cow basis. The correlations for all cows were then tested by Snedecor's method (1948) to see if they all belonged to a common population and, if so, an average correlation derived. Table 6 shows such average correlations for all variables.

For 394 d.f. Snedecor's table for tests of significance gives r = .128 at the 1 per cent level. All the above are therefore highly significant.

Linear regression coefficients for the three larger correlations were as follows:—

Skin Temperature and Air Temperature
b = 0.318; 31 d.f., t = 2.750 1% level.

Respiration Rate and Air Temperature
b = 1.210; 43 d.f., t = 1.690 1% level.

Respiration Rate and Skin Temperature
b = 2.420; 31 d.f., t = 2.750 1% level.

TABLE 4. AVERAGE READINGS OF SKIN AND BODY TEMPERATURES, RESPIRATION AND PULSE RATES AT CORRESPONDING AIR TEMPERATURES

Air Temp. (°F.)	Skin Temp. (°F.)	Rectal Temp. (°F.)	Resp. Rate	Pulse Rate	Number of Readings
36		100.9	18	56	2
37		101.7	18	68	1
38		101.6	18	64	1
39		101.2	20	60	2
40		100.6	18	55	2
41		101.4	24	67	1
42		100.9	22	63	2
43		101.5	21	56	2
44		101.7	22	62	4
45		101.3	28	64	6
47		101.2	22	70	4
48		101.7	22	70	21
49		101.7	22	70	21
50	90.5	101.6	22	69	14
51	91.0	101.8	27	62	20
52	93.3	101.7	40	67	27
53	91.8	101.6	33	67	31
54	93.3	101.7	30	67	34
55	92.6	101.8	31	68	28
56	93.3	101.8	24	72	40
57	94.7	101.8	36	71	34
58	94.0	101.6	39	69	21
59	93.4	101.8	40	70	23
60	93.7	101.5	38	67	29
61	94.2	101.6	39	69	16
62	94.9	101.8	39	69	26
63	95.1	101.8	40	70	12
64	96.4	101.5	44	71	16
65	93.3	101.8	41	70	12
66	95.5	102.0	42	70	7
67	96.4	102.2	47	70	4

TABLE 5. COMPONENTS OF VARIANCE DERIVED FROM ANALYSIS OF VARIANCE FOR SKIN AND BODY TEMPERATURES, AND RESPIRATION AND PULSE RATES

Source of Variation	Skin Temperature		Body Temperature		Respiration Rate		Rate Pulse	
	Actual	%	Actual	%	Actual	%	Actual	%
Animals	0.07	1.17	0.04	19.0	12.41	9.83	35.59	51.63
Days	2.79	46.50	0.01	4.8	55.58	44.02	14.45	20.97
Readings	0.95	15.90	0.06	28.5	0.52	0.41	0.92	1.33
R x A	0.49	8.18	0.001	0	0.00	0	5.33	7.73
R x D	0.01	0.16	0.01	4.8	22.91	18.14	3.76	5.45
D x A	0.27	4.50	0.04	19.0	4.73	3.75	0.50	0.73
R x D x A	1.41	23.50	0.05	23.8	30.11	23.84	8.37	12.14

TABLE 6. AVERAGE CORRELATIONS FOR ALL COMBINATIONS

X1	Skin T.	Skin T.	Air T.	Air T.	Body T.
X2	Air T.	Resp. R.	Body T.	Pulse R	Pulse R
r	.640	.661	.326	.396	.285
X1	Skin T.	Skin R.	Air T.	Body T.	Resp. R.
X2	Body T.	Pulse R	Resp. R.	Resp. R.	Pulse R
r	.373	.391	.613	.359	.439

These regressions are averages of the individual lot regressions for each cow. To see whether the individual cow regressions differed significantly from one another an analysis of error variance was made. In all three cases when the test was applied it was not significant. The regression lines for all cows therefore belonged to a common population.

DISCUSSION

Analysis of Variance

Table 1 shows that there was no significant difference between animals or between twin pairs in skin temperature. The literature indicates that skin temperature does not change as rapidly as air temperature. That it does change is well shown by the results of Thompson, McCroskery and Brody (1951), but the air temperature and conditions prevailing during this trial which was during late autumn were not severe enough to cause a difference between animals in skin temperature. Any difference there may be due to colour and type of coat did not show up on the basis of this evidence. There was a significant difference in skin temperature on different days and throughout the day due to different weather conditions, particularly solar radiation between and within days. The day x animal interaction for skin temperature was highly significant; some days caused cows to react in a different direction to other days. A significant interaction between days and readings was to be expected because of the different weather conditions at a given time on different days.

For body temperature there was a highly significant difference between animals but not between twin pairs. Differences between days and readings were also highly significant. The difference between days and animals was not expected as conditions were not hot enough to result in such differences. It is believed, however, that the differences arose from the effects of advancing pregnancy. Since the twin pairs did not calve on the same day, this may possibly explain the non-significant difference between twin pairs but a significant difference between animals. The difference between readings was probably due to the diurnal trend in body temperature.

Air temperature conditions were sufficient to show a marked difference between animals, twin pairs and days, and readings in respiration rate. This was a direct climatic effect. The animal x day and twin-pair x day interaction were both highly significant, showing that animals and twin pairs reacted differently to air temperature conditions on different days. The reading x day interaction was probably due to different weather conditions at any one reading from day to day.

As with respiration rates, a highly significant difference between animals, twin pairs, days and readings within a day, was found for pulse rates. Pulse rates appear to be a strong individual characteristic of animals, hence twin pairs tend to have similar pulse rates. A difference between days and readings was not expected because pulse rates of cattle are believed to be fairly stable over the air temperature range of 40–60° F (Kibler and Brody, 1949), and most of the measurements were taken over this range, the total range being 37–67° F. Environmental influences apparently did not cause the difference between days and readings. It was probable that as with body temperature the effect was due to advancing gestation. This suggestion is strengthened by the significant day x animal interaction. Since the animals calved at different times, this interaction would be expected to be significant. A significant difference between readings also cannot be explained on the basis of climatic effects. Blaxter (1943) observed the effect of feed and nervous upsets on pulse rates, and it is probable that these were mainly responsible for the difference between readings. Under field conditions it is difficult to standardise for these factors. Feed plus disturbances would obviously vary with different readings on different days.

Table II shows that with skin temperature and respiration rate, day effects caused 44 per cent of the total variance. Inherent differences between animals in pulse rates accounted for 50 per cent of the total variance. Nearly 30 per cent of the variation in body temperature was caused by diurnal trends.

The correlations derived from combinations of all variables are all highly significant statistically, but in only three of them are the correlations of any physiological significance. These were (1) air temperature and respiration rate, $r = .613$ (Gaalaas, 1945; $r = .77$); (2) air and skin temperature, $r = .640$ (Quinlan and Riemerschmid, 1941; $r = .910$); and (3) skin temperature and respiration rate, $r = .661$. However, even these account for only 40 per cent of the total variance.

The linear regression coefficients are of interest. A 1 per cent rise in air temperature on the average produced 0.31° F increase in skin temperature (Riemerschmid and Quinlan, 1941; 0.28° F in the sun and 0.31° F in the shade). An increase of 1° F in air temperature produced an average increase of 1.21 respirations per minute. A 1° F increase in skin temperature produced an average increase of 2.42 respirations per minute. It can be seen that although skin temperature increased with rises in air temperature it did so at a lesser rate, thus decreasing the temperature difference at the skin surface, making it harder to lose heat by radiation, conduction and convection. That there is a rapid rise in respiration rate with air temperature especially after 67° F (Gaalaas, 1945) and 70° F (Kibler and Brody, 1949) has been noted. Possibly this may act by way of skin temperature, but the above results for the regressions of air and skin temperature, and skin temperature and respiration does not assist the theory that air temperature may increase respiration rate by way of increasing the skin temperature, stimulating the thermoreceptors and thus increasing respiration rate. If so, then the two regression coefficients should be nearly equal. The regression coefficient for air and skin tem-

perature shows a lag in skin temperature rise. The temperature of the air breathed by the cow may increase its respiration rate in the first instance (Kleiber and Regan, 1935), but when the skin temperature has risen enough to stimulate the thermoreceptors there may be an impetus to respiration rate because of a more urgent warning to the brain centres and consequently increased heat loss by evaporation. If such were the case the relation between air temperature and respiration rate would be curvilinear. Gaalaas (1945) found his data fitted a curvilinear regression line quite well. With the data in this paper, however, the test of curvilinearity was non-significant and, according to the graph produced by Gaalaas and fitted to the air temperature range experienced in this trial, the relation was virtually linear.

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DIRECT EFFECTS OF CLIMATE ON CATTLE

II. MEASUREMENTS OF SKIN TEMPERATURE IN CATTLE

By M. R. Patchell, The Dairy Research Institute, Palmerston North

(Received for publication, 9 February 1954)

Summary

1. The use of different thermocouples in taking skin temperature measurements with cattle is described.

2. Leaving the hair on and sliding the junction under it gave better results than clipping or shaving the hair.

3. Skin temperature was found to vary widely over the body of the animal being lowest on the extremities.

Introduction

In this second paper of the series reporting observations of the reactions of cattle to the direct effect of climate, the results are presented of a trial to investigate methods of measuring the skin temperature of cattle. The literature on this subject has been adequately reviewed by Findlay (1950) and Thompson, Worstell, and Brody (1952).

Experimental Material and Methods

Dominion Physical Laboratory, New Zealand, kindly supplied on loan a portable potentiometer, Tinsley Model, and four types of thermocouples. These latter had all been checked for calibration and found accurate to within 0.1° c over the range of temperatures for which they were to be used. The references junction was a vacuum flask filled with liquid paraffin and fitted with a thermometer and a wire plunger which served to stir the liquid in the flask.

Later a Cambridge portable potentiometer (workshop model) was purchased and used for skin temperature measurements.

The four types of thermocouples were as follows:—

(1) Bow type—the holder resembled a hacksaw frame with 33 S.W.G. copper constanton wire joined at the centre of the bow. This type had a series of pulleys and a spring so that adjustments could be made to vary the tension on the wire.

(2) Hypodermic needle thermocouple—45 S.W.G. enamelled copper constanton wires soldered at the tip of a hypodermic needle.

(3) Plastic probe thermocouple—a thin tinned copper disc to which was attached two enamelled wires 45 S.W.G. copper constanton, arranged at the end of a hollow tube of plastic.

(4) Disc type thermocouple—32 S.W.G. enamelled constanton and 40 S.W.G. copper soft soldered to a tinned copper disc.

Rising two-year-old Jersey heifers were used to determine what was the repeatability of measurement and to find at what position on

the animals skin temperatures could be taken accurately yet quickly. Nine positions on the right hand side of each animal were selected. The positions were shaved of hair and the thermocouple was applied to each of the nine positions in sequence and the process repeated three times. Five of the positions which gave the best repeatability were taken and then two of the best of these five.

With the Cambridge potentiometer, the reference junction used was crushed ice. The paraffin oil junction with the Tinsley was found to be somewhat impracticable. Its temperature varied with the air temperature and the temperature of the junction had to be noted before the potentiometer was read. As the wire plunger had to be worked before taking each reading, this entailed the collection of more data. A further difficulty was that the temperature of the reference junction was sometimes found to alter while taking a measurement. With the reference junction of crushed ice, however, the temperature remained constant and no adjustment had to be made. Unlike the Tinsley potentiometer, the Cambridge potentiometer gave a constant reading while the junction was held against the skin. At a later stage in this trial three non-milking cows were placed in an indoor feeding barn and trials were made by recording skin temperatures under the following conditions:

(a) Normal with the hair left on;

(b) Clipped;

(c) Shaved.

Eight positions on the right hand side of each animal were used and three readings per position were taken. The animals were tested once on one day and twice on the next day.

Later skin temperatures were taken without shaving or clipping on the same three cows to determine whether skin temperature varied over different parts of the body. Twenty-two positions were selected on each cow on the right hand side of the body, ranging from just above the hoof on the hind leg up and over the body, down the front leg and up to the head and ears. This trial extended over six days with morning and afternoon readings. For all readings the hair was not shaved or clipped and one reading per position was taken.

Results

Of the four thermocouples, the disc type and the hypodermic needle were found to be impracticable. The former had to be taped on to the skin and the wires were fragile and broke easily, while the latter upset the animals and was also fragile. Of the remaining two types the bow type gave a more constant reading than the plastic probe model. However, even with the bow type there was a loss of heat by conduction since the dial reading on the Tinsley potentiometer decreased the longer the junction was held on the position. It was found that with the paraffin oil reference junction the wire plunger had to be worked immediately before each reading, otherwise a drop in temperature occurred.

Table 1 shows the intra-class correlation obtained with the various positions. The equipment used consisted of the bow type thermocouple, a paraffin oil reference junction and a Tinsley potentiometer.

TABLE 1. INTRA-CLASS CORRELATIONS OF SKIN TEMPERATURE ON VARIOUS POSITIONS

Day	Cows used	Position	Readings per position	r_1
1	6	1	3	.900
		2		.669
		3		.056 N.S.
		4		.850
		5		.477 *
		6		.693
		7		.811
		8		.530 *
		9		.713
2	12	1	6	.846
		2		.998
		3		.793
		4		.716
		5		.760
3	12	1	3	.713
		2		.849

All highly significant at 1% level except those marked:
* Significant at 5% level.
N.S. Non-significant.

TABLE 2. ANALYSIS OF VARIANCE OF SKIN TEMPERATURE TAKEN IN THREE DIFFERENT WAYS

Source	d.f.	Mean Squares	F
B. Animals (A.)	647		
Total	2	757.84	N.S.
B. Days (D.)	1	282.23	N.S.
D. x A.	2	1146.64	**
B. Positions (P.)	7	175.06	N.S.
P. x A.	14	213.32	N.S.
P. x D.	7	371.94	N.S.
P. x D. x A.	14	345.00	
B. Types	2	161.14	**
T. x A.	4	0.71	N.S.
T. x D.	2	3.00	N.S.
T. x P.	14	3.51	N.S.
T. x A. x D.	4	1.20	N.S.
T. x A. x P.	28	2.53	N.S.
T. x D. x P.	14	7.90	*
T. x D. x A. x P.	28	3.37	
Error	504	0.56	

Table 2 shows the analysis of variance to see if there was a significant difference between leaving the hair normal, clipping it or

shaving it. The analysis is similar to the "time" analysis described by Wilm (1945). The equipment for these measurements was the bow type thermocouple, the Cambridge potentiometer and the reference junction of crushed ice.

The degrees of freedom for between types were split as follows:

B. Types			
Subdivided into	d.f.	M.S.	F.
Clipped v Shaved	1	9.87	N.S.
Normal v (clipped and shaved)	1	312.41	**
T x D x A x P (error for testing)	28	3.37	

Means for Types °F.	
Normal	88.77
Clipped	88.45
Shaved	88.15

An analysis of variance similar to that seen in Table 2 was worked out for the data taken from 22 positions. A highly significant difference between positions was found. The range of skin temperature was 74.2 to 95.0° F; mean = 88.3 F; s = 1.47; C = 1.7%.

The mean skin temperature per position is shown in Table 3.

TABLE 3. MEAN SKIN TEMPERATURE PER POSITION FROM DATA ON THREE COWS WITH TWO READINGS PER DAY FOR SIX DAYS: 22 POSITIONS ON EACH ANIMAL

Position	1	2	3	4	5	6	7	8	9	10	11
Skin Temp. (°F.)	89.2	82.0	91.2	90.5	90.6	89.6	84.9	82.1	89.0	89.2	88.9
Position	12	13	14	15	16	17	18	19	20	21	22
Skin Temp. (°F.)	88.8	89.0	88.8	89.6	90.0	89.0	88.3	84.2	83.3	88.9	90.9

DISCUSSION

With the intra-class correlation analysis it can be seen that Positions 1 and 2, which were the left and right hip positions about midway between the hip bone and the spine, gave the best repeatability. Here the curvature of the body allowed better tension of the thermocouple wires. Some of the positions, e.g., Position 3, on the hind leg just below the hock, gave poor repeatability. It was difficult to ensure the same constant pressure from reading to reading with this position. Other positions gave varying results, but the right hip region was

chosen for subsequent routine measurements because it gave a good repeatability, it was in a handy position and did not disturb the animal. When working outside, it was often noticed that if clouds passed over the face of the sun there was shortly afterwards a drop in skin temperature. This occurred even though the positions were on the shaded side of the body. This was probably due to the clouds cutting off the direct solar radiation.

The significant drop in skin temperature which occurred when the hair was clipped or shaved supports the work of Skorohodjko *et al.* (1946). However, even though the temperature recorded is higher when the junction is slid under the hair it may not necessarily be the skin temperature, but something which is a fraction lower than the true skin temperature, because unless extreme care is taken a few fine hairs may still be between this junction and the skin. Some cows have a closer and finer hair coat than others and it is difficult to displace all the hairs, slide the junction under and smooth the hair back over the junction. If a few hairs are between the junction and the skin this will result in a small layer of air trapped between the two. Air is a poor conductor of heat and the temperature drop across such a layer of air would be considerable.

The extremities of the animal clearly have a lower skin temperature than the trunk region. These trials were made under moderate air temperature conditions so that whether or not the extremities have a higher skin temperature than the trunk under conditions of high air temperature (as in the case in man) is still not certain. However, for accurate measurements of skin temperature it seems that the trunk is the best place to measure as there was little variation between the different positions on the trunk of the animal.

The great advantage of using thermocouples for skin temperature measurements is the ease with which they can be remade, and provided they are used with care they can be quite accurate. Their chief disadvantage is the great care needed in handling, the need for a cold junction at a constant temperature, and the various intrinsic and physiological errors involved in their use. The most accurate methods of taking skin temperatures of course is by means of a radiometer. This has been successfully used by Hardy (1934) on human beings. However, the calculation of the temperature entails a knowledge of the emissivity of the skin, which for cattle has not been determined. The radiometer does not suffer from any of the disadvantages to which thermocouples are subject.

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MEASUREMENT OF FEED INTAKE OF GRAZING CATTLE AND SHEEP

V. ESTIMATION OF THE FEED-TO-FAECES RATIO FROM THE NITROGEN CONTENT OF THE FAECES OF PASTURE FED CATTLE

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(Received for publication, 4 March, 1954)

Summary

Twenty-two digestibility trials conducted on different pasture feeds have been used to derive the relationship between faecal nitrogen, faeces output, and pasture intake on an organic matter basis. The factor Y (feed-to-faceas ratio = the riciprocal of indigigestibility ratio) by which faeces output must be multiplied to yield pasture intake, shows a reasonable linear relationship with nitrogen concentration x of the faeces. The derived formula $Y = x + 0.9$ has a standard error of 9 per cent for a single cow, for a single feed, for a 10-day period. The range of digestibility of the pasture studied was 58 to 84 percent.

Introduction

The indirect method of estimating grass consumption by grazing cows which has been developed at this Station requires separate estimates of faeces output, and of the feed-to-faeces ratio ("intake factor"), which is a function of digestibility. Estimation of faeces output by the chromic oxide technique was reported in Part IV of this series [1]. In Part I[2] a method was proposed for calculating the digestibility of grass consumed by sheep, from the nitrogen content of their faeces. Modification of the method for use with cattle form the subject matter of this paper.

Experimental Procedure

Digestibility Trial Procedure

The data were derived from two series of digestibility trials. The first series (15 trials) concluded in 1948, were conducted on paspalum-dominant and on mixed dairy pastures of the ryegrass/white-clover/cocksfoot variety at widely different stages of growth. Two dry cows were used in each of the six paspalum trials, and three in the nine mixed pasture trials. The cows were drawn from a small group accustomed to the procedure. The test period was ten days following a six-day pre-period. Faeces were collected in bags[3].

The second series (7 trials) carried out in 1951/52 was initiated to supplement the data already available, and covered similar pasture except that no paspalum was included. Different animals were used wherever possible to increase the size of population covered. Pre-periods were increased to three-to-four weeks. The test period was extended to 15 days. To avoid distrubance of cows unaccustomed to bagging, attendants were employed to collect the dung directly as it was voided.

Chemical Methods

Nitrogen was estimated by the Kjeldahl procedure as modified by White *et al.* [4], and ash by ignition of samples in a muffle furnace at 580°c for 1½ hr. All results are quoted on an organic matter basis.

TABLE 1. DIGESTIBILITY TRIAL DATA (Organic Matter Basis)

C = nitrogen excreted in faeces per 100g. grass consumed

x = nitrogen (%) in faeces

D = digestibility of grass

$Y_{obs.}$ = observed intake factor (feed-to-faeces ratio)

$Y_{calc.}$ = estimated intake factor ($= x + 0.9$)

$Z_{obs.}$ = observed starch equivalent intake factor

$Z_{calc.}$ = estimated starch equivalent intake factor ($= x - 0.37$)

Trial	C	x	D	$Y_{obs.}$	$Y_{calc.}$	$Z_{obs.}$	$Z_{calc.}$
			(Series I: 10 day period)				
Paspalum							
1	.72	2.30	68.9	3.22	3.20	1.90	1.93
	.71	2.48	71.2	3.48	3.38	2.06	2.11
2	.64	1.53	58.2	2.39	2.43	1.02	1.16
	.67	1.61	58.5	2.41	2.51	1.02	1.24
17	.69	2.44	71.9	3.56	3.34	2.22	2.07
	.67	2.30	71.0	3.45	3.20	2.15	1.93
18	.75	2.18	65.7	2.92	3.08	1.65	1.81
	.72	2.32	69.2	3.25	3.22	1.84	1.95
23	.76	2.04	62.9	2.69	2.94	1.45	1.67
	.66	1.92	65.9	2.93	2.82	1.58	1.55
13	.82	3.20	74.3	3.89	4.10	2.71	2.83
	.78	3.26	76.0	4.17	4.16	2.90	2.89
Mixed Pastures							
117	.82	4.02	79.6	4.90	4.92	3.63	3.65
	.82	3.98	79.4	4.85	4.88	3.59	3.61
	.93	3.88	76.1	4.18	4.78	3.10	3.51
118	.80	3.83	79.1	4.78	4.73	3.54	3.46
	.75	3.81	80.4	5.10	4.71	3.78	3.44
	.78	3.81	79.6	4.90	4.71	3.63	3.44
120	.93	3.91	76.3	4.22	4.81	3.00	3.54
	.88	3.60	75.5	4.08	4.50	2.90	3.23
	.85	3.71	77.2	4.37	4.61	3.11	3,34
123	.63	2.92	78.4	4.63	3.82	3.31	2.55
	.65	2.87	77.2	4.40	3.77	3.14	2.50
	.65	2.88	77.4	4.42	3.78	3.16	2.51
124	.61	2.35	74.0	3.85	3.25	2.50	1.98
	.66	2.66	75.4	4.06	3.56	2.63	2.29
	.65	2.52	74.3	3.89	3.42	2.52	2.15
125	.63	2.46	74.3	3.89	3.36	2.43	2.09
	.72	2.62	72.5	3.64	3.52	2.28	2.25
	.68	2.59	73.6	3.79	3.49	2.37	2.22
F29	.82	4.10	80.0	5.00	5.00	3.71	3.73
	.82	3.90	79.0	4.76	4.80	3.54	3.53

TABLE 1—Continued

Trial	C	x	D	Y obs.	Y calc.	Z obs.	Z calc.
51	.85	3.03	71.8	3.55	3.93	2.30	2.66
	.82	2.75	70.2	3.36	3.65	2.18	2.38
10	.79	4.70	83.2	5.95	5.60	4.68	4.33
	.79	4.72	83.2	5.95	5.62	4.68	4.35
			(Series II: 15 day period)				
Mixed Pastures							
A	.73	4.64	84.3	6.37	5.54	5.04	4.27
	.82	4.88	83.3	5.99	5.78	4.74	4.51
	.86	4.98	82.8	5.82	5.88	4.60	4.61
	.81	4.82	83.2	5.95	5.72	4.71	4.45
	.80	4.78	83.3	5.99	5.68	4.74	4.41
	.83	5.00	83.4	6.02	5.90	4.76	4.63
B	.67	2.36	71.6	3.52	3.26	2.22	1.99
	.67	2.46	72.8	3.68	3.36	2.33	2.09
	.70	2.45	71.4	3.50	3.35	2.21	2.08
C	.79	3.69	78.4	4.63	4.59	3.39	3.32
	.82	3.85	78.8	4.72	4.75	3.45	3.48
	.82	3.79	78.4	4.63	4.69	3.39	3.42
D	.94	2.86	67.0	3.03	3.76	1.83	2.49
	.87	2.83	69.4	3.27	3.73	1.97	2.46
	.88	2.75	67.8	3.11	3.65	1.88	2.38
E	.84	2.53	66.6	3.00	3.43	1.71	2.16
	.82	2.49	67.1	3.04	3.39	1.74	2.12
	.82	2.57	67.9	3.12	3.47	1.78	2.20
F	.89	4.64	80.8	5.21	5.54	4.04	4.27
	.95	4.89	80.6	5.16	5.79	4.00	4.52
	.83	4.77	82.5	5.72	5.67	4.44	4.40
G	.91	4.77	81.0	5.27	5.67	4.01	4.40
	.96	4.46	78.6	4.67	5.36	3.55	4.09
	.87	4.69	81.4	5.38	5.59	4.09	4.32

RESULTS AND DISCUSSION

The method formerly outlined of calculating the digestibility of pasture organic matter by sheep depended on the assumed constancy (C) of the nitrogen extracted in faeces per unit intake of organic matter[2].

The value of C can be derived from the equation

$$C = x\,I \quad \text{..... (i)}$$

where x = nitrogen concentration in faeces
I = indigestibility ratio of the feed.

Since the intake factor Y is the reciprocal of I, equation (i) may be written $C = \frac{x}{Y}$ or

$$Y = \frac{x}{C} \quad \text{..... (ii)}$$

The efficiency of equation (ii) for predicting the intake factor would depend on the constancy of C. Various workers [5], [6], [7] have pointed out that C is by no means constant and examination of the data in Table 1 reveals this to be so in the present investigations. A more direct approach to the problem is to consider the regression of Y on x leading to a "best" prediction equation of the form $Y = bx + a$.

In view of the classification of the data (22 trials with varying numbers of animals (Table 1) and the predominant contribution of differences between trials to the total variability, the required prediction formula and its error of estimate were calculated from the estimated relevant components of variance and covariance. This in effect ensures a proper weighting of the contributing sources of variation appropriate to the desired application of the results to an individual animal grazing a single type of pasture. The author is indebted to Dr. A. H. Carter for the method of analysis which is indicated in Table 2.

The derived formula is

$$Y = 0.97x + 1.02 \pm 0.39 \ (9.1\%) \quad \text{..... (iii)}$$

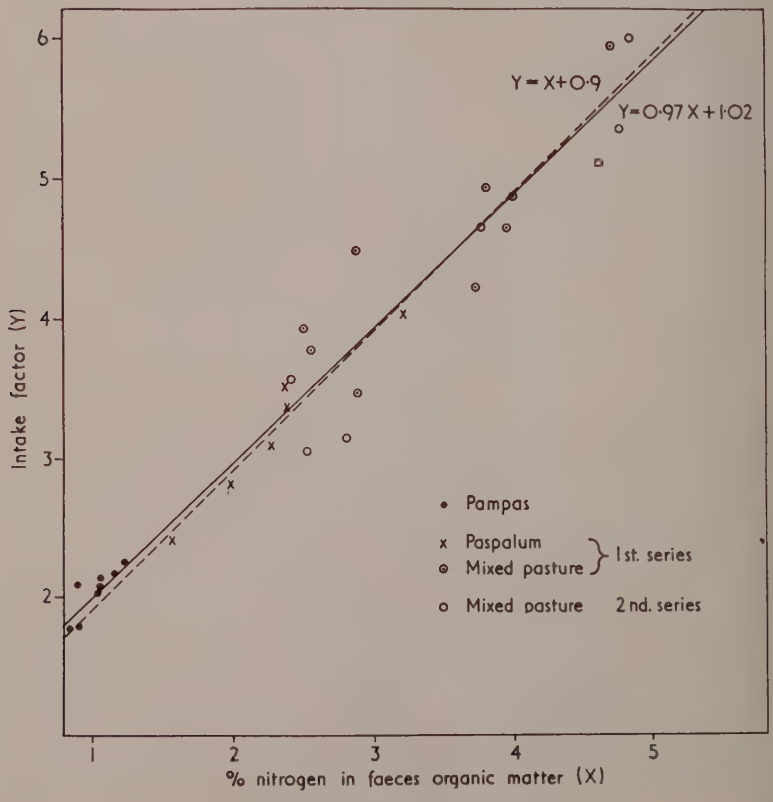

Fig. 1.—Plotted from trial means.

TABLE 2.—ANALYSIS OF VARIANCE AND COVARIANCE

y = organic matter intake factor; z = starch equivalent intake factor; x = nitrogen percentage

$\bar{y} = 4.26$; $\bar{z} = 2.98$; $\bar{x} = 3.35$

		d.f.	(x^2)	(y^2)	(z^2)	(xy)	(xz)
Total	: Mean square/product	59	1.0015	1.0761	1.1290	.9684	1.0083
Within Trials	: Mean squares/product (M_w)	38	.0114	.0377	.0201	.0057	.0038
	(= variance/covariance components (V_w)						
Between Trials	: Mean spuares/products (M_b)	21	2.7930	2.9551	3.1356	2.7106	2.8260
	: Variance/covariance components* (V_b)		1.0247	1.0748	1.1478	.9966	1.0398
Total	: Variance/covariance components (V_b + V_w)		1.0364	1.1125	1.1679	1.0023	1.0436

* Obtained by equating M_b to its expected value, $V_w + 2.714\ V_b$

	y on x	Z on x
Regression estimates		
b	$1.0023 \div 1.0364 = 0.97$	1.01
a ($= \bar{y} - b\bar{x}$)	1.02	−0.39
Equation $Y = bx + a$	$Y = 0.97x + 1.02$	$Z = 1.01x - 0.39$
Residual variance s^2	$1.1125 - b\ (1.0023) = 0.1432$	0.1169
Variance of a ($= s^2/22$)	.0065	.0053
S.E. of Y (approximate)	$\sqrt{0.1497} = 0.386$	$\sqrt{0.1222} = 0.350$
Coefficient of variation	9.1%	11.7%
Taking b = 1	$Y = x + 0.91 \pm .386$	$Z = x - 0.37 \pm .350$

For practical purposes the above formula for the intake factor may, with negligible reduction in accurasy, be simplified to

$$Y = x + 0.9 \quad \text{(iv)}$$

The regression lines calculated from equations (iii) and (iv) are shown in Fig. 1. The plotted points were derived from trial means. Means from eight pampas digestibility trials are also shown. The data from these trials were not included in the regression analysis because pampas, though a forage material, cannot be clasified as a pasture herbage. In addition, the variability among the pampas data was much smaller than among the pasture results and the inclusion of pampas in the analysis would have given a false impression of the accuracy of an equation intended for use with mixed pasture. It is of interest to note, however, that the equation appears valid for the pampas data.

In applying the above formula to studies of the enegetics of milk production on grassland, the intake of *digestible* organic matter is more likely to be required. The appropriate intake factor, W, in this case is the ratio of organic matter digested, i.e. feed- minus-faeces: faeces organic matter. Thus from the equation (iv)

$$W = Y - 1 = x - 0.1 \quad \text{(v)}$$

The standard error of prediction of W is 11.8 per cent.

Feed consumption is also conveniently expressed, for special purposes, in terms of digestible energy as starch equivalent (S.E.). The relationship between the nitrogen content of faeces, x, and the S.E. intake factor, Z, has therefore been derived by using similar statistical methods of analysis. The resulting fomula is

$$Z = x - 0.37 \pm 0.35 \quad \text{(vi)}$$

The standard error is 11.7 per cent.

From equations (iv) (v) and (vi), therefore ,it is possible to derive appropriate intake factors for total organic matter, digestible organic matter and starch equivalent.

Forbes [6] and Woolfolk *et al.* [7] have criticised the faeces nitrogen approach to this problem on the grounds of accuracy. These present modifications, however, lead to estimations of intake of sufficient accuracy for a wide variety of purposes. In addition, the dependence of the method on a reliable and simple chemical estimation like that of nitrogen makes it much more satisfactory for large-scale field work than other methods, e.g., those based on chromogen or lignin which have yielded more precise estimates in closely controlled digestibility trials.

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EFFECTIVENESS OF THERAPEUTANTS INCLUDING ANTIBIOTICS IN PREVENTING DEVELOPMENT OF BLAST OF STONE FRUIT (*Pseudomonas syringae* van Hall)

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Summary

Tests have been carried out to determine the effect of therapeutants, including antibiotics, in preventing infection of seedling peach trees by *Pseudomonas syringae* under glasshouse conditions. Compounds were applied as foliage sprays before plants were inoculated.

Streptomycin sulphate and dihydrostreptomycin sulphate were the most effective compounds in preventing development of the disease. Streptomycin gave significant control at all concentrations from 1000 μg./ml. to 50 μg./ml. Dihydrostreptomycin significantly reduced the number of lesions at concentrations from 1000 μg./ml. to 100 μg./ml. When plants were sprayed with streptomycin and dihydrostreptomycin at a concentration of 100 μg./ml., lesions developed at 18.3 per cent of the inoculation points, as compared with 88.3 per cent on check plants.

Aureomycin, terramycin and chloromycetin significantly reduced the number of lesions at high concentrations, but were not as effective as streptomycin or dihydrostreptomycin.

No other compound was effective.

Chloromycetin, polymyxin, thiolutin, Bordeaux mixture, copper 8-quinolinolate and Murfixtan were phytotoxic at some concentrations. No phytotoxic effects were observed with any other compound.

Introduction

A bacterial disease caused by *Pseudomonas syringae* van Hall, is responsible for serious losses of stone fruit trees in nurseries and orchards throughout New Zealand (Dye, D. W., 1954). So far as the authors are aware no satisfactory measures for combating this disease on stone fruit have been reported. Elliot (1951) in reviewing control measures for *Ps. syringae,* lists resistant varieties, crop rotation, pruning and Bordeaux sprays as being most effective on some hosts. Moore (1947) found that foliage spraying with a copper-containing bactericide and frame working with resistant varieties offered most promise against a similar disease, bacterial canker *(Pseudomonas mors-prunorum* Wormald), on cherry and plum trees in England.

In vitro studies of the effect of antibiotics on *Ps. syringae* (Dye, M. H., 1954) indicated that streptomycin, dihydrostreptomycin, aureomycin, terramycin and polymyxin inhibited the causal organism of stone fruit blast at low concentrations. Results of a preliminary screening of a number of compounds for control of this disease have been published (Dye, D.W., 1953). The present paper records attempts to find a control for blast of stone fruit by foliar application of therapeutants.

Experimental Methods

Seedling peach trees (*Prunus persica* Sieb & Zucc) approximately 12 in. high growing vigorously in pots in a glasshouse were used as host plants. The stems were pricked lightly with a sterile needle at 20 separate points and sprayed with a solution or suspension of the test substance in distilled water. When dry they were sprayed with a broth culture of a pathogenic strain of *Ps. syringae*. The organism was maintained on Difco nutrient agar. Inoculum was prepared by growing the organism for 24 hours at 28°C. in Difco nutrient broth plus 0.5 per cent glucose. The number of viable bacteria in the inoculum, determined by plate counts, ranged from 2.47×10^9 to 5.69×10^9 per ml.

Considerable difficulty was experienced initially in infecting plants artificially and the conditions required for infection are still incompletely known. Under the following conditions, however, the disease developed satisfactorily. After inoculation, plants were placed in an insulated cabinet maintained at 12.0° ± 0.8°C. and 98-100 per cent relative humidity for three days. The humidity was maintained automatically with a water mist produced by an atomizer. The mist formed a fine film on leaves but did not cause run off. After three days the plants were removed to a glass cabinet in which the temperature was maintained at 16° ± 6°C. and the relative humidity at 90-100 per cent. Infection was recorded seven days after inoculation.

Due to lack of incubator space the trials were carried out in two series, Trial A comprising only antibiotics and Trial B comprising other therapeutants. Separate experiments were carried out at each concentration, with all compounds within a series included in each experiment. The most effective antibiotic from Trial A, namely streptomycin, was included in the second trial for comparison. Each concentration of each substance was tested on six plants. The following compounds were investigated:—

Trial A

Streptomycin sulphate	725 units/mg.
Dihydrostreptomycin sulphate	720 units/mg.
Aureomycin hydrochloride (chlorotetracycline)	550 μg./mg.
Crude Terramycin hydrochloride (oxytetracycline)	490 μg./mg.
Chloromycetin	750 μg./mg.
Crude Thiolutin	660 μg./mg.
Polymyxin B sulphate	10,000 units/mg.
Distilled water	

The antibiotics were applied at concentrations of 1000 μg./ml., 500 μg./ml., and 100 μg./ml. In addition streptomycin and dihydrostreptomycin were applied at 50μg./ml.

Trial B

Flit 406 (50% N trichloromethylthio-tetrahydro-phthalimide): 1, 2 and 3 lb. per 100 gal. water.

Dithane Z78 (65% zinc ethylene bisdithiocarbamate): 1, 2 and 3 lb. per 100 gal. water.

Ascospray (2½% phenyl mercury chloride):
1, 2 and 3 lb. per 100 gal. water.

Tetroc (97.8% tetrachloro-p-benzoquinone):
1, 2 and 3 lb. per 100 gal. water.

Copper 8-quinolinolate:
1, 2 and 3 lb. per 100 gal. water.

Murfixtan (0.8% phenyl mercury salt of naphthyl methane sulphonic acid):
1 in 200, 1 in 150 and 1 in 100.

Bordeaux mixture (copper sulphate, hydrated lime, water):
2-4-100, 4-8-100 and 6-8-100.

Streptomycin sulphate (725 units/mg.): 100 μg./ml.

Distilled water.

All compounds were made up into solution or suspension with distilled water. In Trial B, Agral L, a proprietary wetting agent, was added to each mixture except streptomycin sulphate, at the rate of 2 ml. per gallon.

Results

Results are presented in Tables 1 and 2.

TABLE 1. THE EFFECT OF VARIOUS ANTIBIOTICS ON BLAST OF STONE FRUIT
(Trial A)

Concentration (μg./ml.)	Equivalent number of positive lesions out of 120				Means of equivalent angles				Average lesion size (mm.)			
	1000	500	100	50	1000	500	100	50	1000	500	100	50
Treatment												
1. Streptomycin sulphate	2	3	22	79	8.1	9.7	25.6	54.3	2.20	2.14	2.46	3.85
2. Dihydrostreptomycin sulphate	2	5	22	98	7.2	11.9	25.1	64.8	2.00	2.25	2.36	3.88
3. Aureomycin hydrochloride	63	90	78	—	46.5	60.0	53.6	—	2.56	2.88	2.71	—
4. Terramycin hydrochloride (crude)	87	81	84	—	58.6	55.0	56.8	—	3.49	3.38	2.77	—
5. Chloromycetin	60	58	86	—	45.1	44.1	58.1	—	2.48	3.28	2.72	—
6. Thiolutin (crude)	108	93	96	—	71.5	61.8	63.6	—	4.04	3.99	2.96	—
7. Polymyxin B sulphate	96	98	100	—	63.7	64.7	65.7	—	3.22	2.86	3.21	—
8. Water	111	107	106	114	74.4	71.0	70.4	76.5	4.06	4.14	3.28	4.38
Differences necessary for significance			5%				11.9					
			1%				15.8					

TABLE 2. THE EFFECT OF VARIOUS THERAPEUTANTS ON BLAST OF STONE FRUIT

(Trial B)

Concentration lb./100 gal.	Equivalent number of positive lesions out of 120			Means of equivalent angles			Average lesion size (mm.)		
	1	2	3	1	2	3	1	2	3
Treatment									
1. Flit 406	108	96	104	71.9	63.6	68.3	3.91	2.90	3.10
2. Dithane Z78	113	114	117	76.1	77.3	80.5	3.49	3.88	4.61
3. Ascospray	107	111	110	70.8	74.0	73.0	3.07	3.54	4.35
4. Tetroc	113	92	119	75.9	60.9	84.1	3.53	3.01	4.30
5. Copper 8-quinolinolate	113	113	115	76.3	76.1	77.9	3.39	3.91	3.24
6. Murfixtan*	95	112	103	62.8	75.1	68.0	3.29	3.55	3.27
7. Bordeaux mixture**	97	117	104	63.8	81.2	68.6	4.48	5.11	3.70
8. Streptomycin sulphate †	5	10	14	12.0	16.5	20.0	2.13	2.25	3.02
9. Water	115	116	109	77.9	79.6	72.1	3.55	4.58	4.61
Differences necessary for significance 5%					13.2				
1%					17.4				

* Concentrations 1, 2 and 3 = 1 in 200, 1 in 150, 1 in 100

** „ „ = 2-4-100, 4-8-100, 6-8-100

† Concentration at all times = 100 μg. per ml. = approx. 1/10 lb. per 100 gal.

Streptomycin sulphate and dihydrostreptomycin sulphate were the most effective compounds. Streptomycin gave significant control at all concentrations. Dihydrostreptomycin significantly reduced lesion numbers at concentrations from 1000 μg./ml. to 100 μg./ml., but not at 50 μg./ml. Lesions developed at 18.3 per cent of the inoculation points when plants were sprayed with streptomycin and dihydrostreptomycin at a concentration of 100 μg./ml. as compared with 88.3 per cent on check plants. Although aureomycin, terramycin and chloromycetin significantly reduced the number of lesions at high concentrations, the degree of control was considerably less than that obtained with streptomycin and dihydrostreptomycin. None of the other substances was significantly effective at any of the concentrations used. Streptomycin and dihydrostreptomycin not only considerably reduced the number of lesions which formed, but also reduced lesion size at all concentrations above 50 μg./ml. A comparison of lesion numbers and lesion sizes on plants sprayed with streptomycin at 50 μg./ml. and 100 μg./ml. indicates that the lower limit of significant control by this antibiotic was near 50 μg./ml.

Damage consisting of leaf spotting and defoliation was apparent on plants sprayed with chloromycetin and polymyxin at 1000 and 500 μg./ml., but not at 100 μg./ml. Suspensions of thiolutin containing 1000 μg./ml. caused slight leaf spotting. None of the other antibiotics caused any apparent phytotoxicity at any of the concentrations used. Severe leaf damage and defoliation was caused by Bordeaux mixture at all concentrations used. Leaf spotting and slight defoliation was caused by copper-8-quinolinolate at all concentrations, and by Murfixtan at 1 in 100 and 1 in 150.

Discussion

The high degree of control obtained with streptomycin and dihydrostreptomycin in the presence of large numbers of pathogenic bacteria is an encouraging result. There are numerous factors influencing the effectiveness of the antibiotics in plants which require clarification before any critical comparison can be made with *in vitro* studies. It is nevertheless of interest to note that although polymyxin inhibited *Ps. syringae* at low concentrations in the laboratory (Dye, M.H., 1954) and is reported to be bactericidal to many bacteria, (Bliss *et al.*, 1949; White *et al.*, 1949) this compound failed completely to prevent infection of peach seedlings by *Ps. syringae*. This negative result may well be associated with the phytotoxicity of polymyxin to peach seedlings, since any beneficial effects may have been nullified by increased infection as a result of injury to the plant caused by this compound.

Again, differences in inoculum count greatly affect the efficiency of many antibiotics, particularly polymyxin (Bliss *et al.*, 1949). It is possible, therefore, that with a lower inoculum concentration than that used in the present study, a greater degree of control by some of the antibiotics may be obtained.

The stability of the compounds is also obviously important. Under certain conditions aureomycin loses activity rapidly (Chandler and Bliss, 1948). On the other hand chloromycetin is stable under a much wider range of conditions (Bartz, 1948). These properties may account for the finding that aureomycin and chloromycetin were approximately equally effective *in vivo*, although aureomycin was far more effective than chloromycetin *in vitro*.

Acknowledgments

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IN VITRO STUDIES OF THE EFFECT OF ANTIBIOTICS ON *Pseudomonas Syringae*

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(Received for publication, 25 March 1954)

Summary

The inhibitory effect of seven antibiotics on a strain of *Pseudomonas syringae* pathogenic to peach seedlings has been studied *in vitro*. Aureomycin, streptomycin, dihydrostreptomycin, terramycin and polymyxin all inhibited the growth of the test organism within the range 0.1 μg./ml. to 4.6 μg./ml. after 24 hours incubation. Aureomycin was the most effective compound while chloromycetin and thiolutin were the least effective compounds.

When 10 μg./ml. of streptomycin sulphate was included in broth cultures of *Ps. syringae* containing 2.05×10^6 bacteria per ml., no viable organisms were detected after 24 hours incubation. At a concentration of 5 μg./ml. of streptomycin, viable bacteria were present after 24 hours incubation, but not after 48 hours incubation. At lower concentrations of streptomycin there was an initial reduction in the number of viable bacteria followed by a rise in count.

Introduction

Pseudomonas syringae van Hall has been identified by Dye, D. W. (1954) as the causal organism of a disease known as "blast of stone fruit". The disease has been particularly severe on stone fruit trees in this country during the past few years. No adequate control measures are known.

Encouraging reports of control of plant bacterial diseases with antibiotics experimentally have been published by a number of authors. Brown and Heep (1946) reported the elimination of *Xanthomonas pruni* from infected plum-tree budwood by soaking the bud sticks in a streptomycin solution. Control of seed-borne bacterial diseases with antibiotics was reported by Ark (1947, 1949), Goodman and Henry (1947), Van Schaack (1948), and Smith (1949). Under glasshouse conditions, the spraying of tomato plants with streptomycin controlled infection by the leaf-spot organism *Pseudomonas punctulans* (Ark, 1949). Absorption and translocation of antibiotics resulting in systemic control of certain plant bacterial diseases was reported by Blanchard (1951) and Mitchell *et al.* (1952). Reviews of literature on antibiotic compounds in relation to plant disease were published by Weindling *et al.* (1950), and by Anderson and Gottlieb (1952).

This paper records the results of *in vitro* experiments to determine the minimum concentration of a number of antibiotics required to inhibit the growth of *Ps. syringae*. In *in vivo* studies by Dye, D. W. (1953) and Dye, D. W. and Dye, M. H. (1954), streptomycin was found to be the most effective of these antibiotics in preventing infection of peach seedlings by *Ps. syringae*. It was decided therefore to carry out further *in vitro* studies with streptomycin, and the results of an investigation into the bactericidal action of streptomycin on *Ps. syringae* are included in this paper.

Materials

The following antibiotics were used:—

Streptomycin sulphate	720 units/mg.
Polymyxin B sulphate	725 units/mg.
Aureomycin hydrochloride (chlortetracycline)	550 μg./mg.
Crude Terramycin hydrochloride (oxytetracycline)	490 μg./mg.
Chloromycetin (chloramphenicol)	750 μg./mg.
Polymyxin B sulphate	10,000 units/mg.
Crude Thiolutin	660 μg./mg.

Minimal Inhibitory Concentration

Method

Each compound was assayed microbiologically by a tube dilution technique to determine the minimum concentration required to inhibit the growth of a strain of *Ps. syringae* pathogenic to peach trees. All substances were taken into solution with distilled water with the exception of thiolutin. This compound is only sparingly soluble in water and was therefore first dissolved in acetone with subsequent dilution to a concentration of 4.9 per cent acetone in the first assay tube. Preliminary experiments indicated that acetone concentrations of 5 per cent or less did not prevent growth of *Ps. syringae*. The organism was maintained on Difco penassay agar, and was incubated at 28°C. for 24 hours in Difco penassay broth to provide inoculum. Difco nutrient broth, to which was added 0.5 per cent glucose, was used as the assay medium. Metal caps were used in place of cotton wool bungs on all test tubes. This method resulted in a considerable saving in time with no increase in the number of contaminated tubes.

A preliminary geometric series assay was carried out with all compounds to determine the approximate inhibitory concentration. An arithmetic series was then set up with concentrations within the range indicated by the preliminary assay. There was sufficient difference in concentration between adjacent tubes to give clear cut end points. Results were recorded after 24 and 48 hours incubation at 28°C. Three separate assays, each one in triplicate, were carried out on each substance. The end point was taken as lying between the two adjacent concentrations at which growth was and was not visible by eye. The means of these two concentrations for all assays are presented in Table 1.

Results and Discussion

TABLE 1. INHIBITION OF *PS. SYRINGAE IN VITRO* BY SEVEN ANTIBIOTICS

	MINIMAL INHIBITORY CONCENTRATION μg./ml.*			
Hours of incubation	Aureomycin	Streptomycin	Dihydro-Streptomycin	Terramycin
24	0.1 to 0.6	0.3 to 0.8	0.6 to 1.0	0.6 to 2.0
48	0.7 to 2.5	1.1 to 5.6	1.1 to 5.6	0.8 to 4.7

Hours of incubation	MINIMAL INHIBITORY CONCENTRATION μg./ml.*		
	Polymyxin	Thiolutin	Chloromycetin
24	1.0 to 4.6	10.8 to 15.4	24.4 to 30.8
48	1.0 to 5.1	15.4 to 18.2	> 53.7

* Mean values from nine determinations of the two adjacent concentrations at which growth was and was not visible

Table 1 shows the lowest concentration of the antibiotics in μg./ml. which inhibited the growth of *Ps. syringae* under the above conditions. In several assays, aureomycin, streptomycin and terramycin all had the same end point. On no occasion, however, did any compound inhibit the growth of *Ps. syringae* at a concentration lower than did aureomycin.

The results are in general agreement with those of Katznelson and Sutton (1951) and MacKay and Friend (1953). The former authors found that terramycin was the most effective compound of six antibiotics tested *in vitro* against plant pathogenic Pseudomonads, followed by streptomycin and aureomycin. Of two strains of *Ps. syringae* examined, one was more sensitive to aureomycin and streptomycin than to terramycin, while with the other strain the position was reversed. MacKay and Friend (1953) found that streptomycin was the most effective of several antibiotics assayed against a strain of *Ps. syringae* pathogenic to dwarf beans. Although the differences in sensitivity of various strains of *Ps. syringae* to aureomycin, streptomycin and terramycin indicated by these authors is small, it is clear that the strain responsible for a particular disease should be used in laboratory screenings of potential therapeutants for that disease.

Bactericidal Action of Streptomycin

Hamre *et al.* (1946) showed that streptomycin was bactericidal for *Klebsiella pneumoniae*. The effect was related to the concentration of streptomycin, the assay medium employed and the period of time bacteria were exposed to the drug. In addition, these authors showed that a greater concentration of streptomycin was required for bactericidal action when bacteria were in the resting state, than when they were actively multiplying. Working with *Escherichia coli* in the resting state, Strauss (1947) showed that the bactericidal action of streptomycin was related to the concentration of organisms.

Method

The strain of *Ps. syringae* and the test medium were the same as were used for the bacteriostatic assays. Streptomycin was added to 10 ml. quantities of inoculated broth in test tubes to give final concentrations of 10, 5, 1 and 0.5 μg./ml. The number of viable bacteria at the commencement of the assays was approximately 2.05×10^6 per ml. After 2, 5, 24 and 48 hours incubation at 28°c., 1 ml. was removed from each tube for dilution and plate counts. At the same times a further 0.1 ml. was transferred from each tube to flasks containing 50 ml. sterile broth and reincubated for 72 hours. Free strepto-

mycin was thus diluted to a sub-inhibitory concentration and permitted a check on tubes which had been "sterilised" by streptomycin. Quadruplicate assays were carried out on two separate occasions.

Results and Discussion

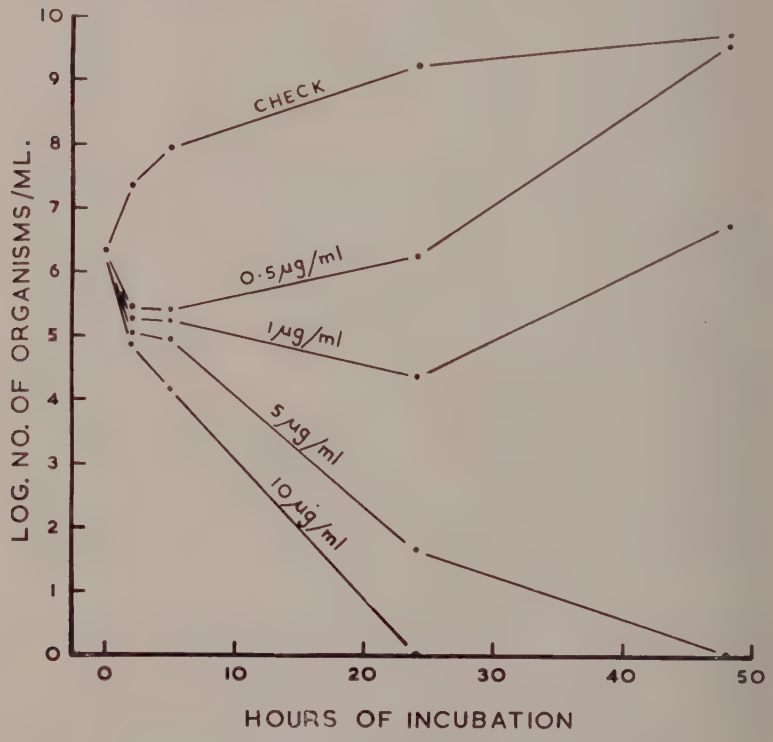

Fig. 1.—The bactericidal action of streptomycin on *Ps. syringae*.

Results are presented graphically in Fig. 1, each point being the mean of eight determinations. The results are in general agreement with those of authors studying human pathogenic bacteria. Hamre *et al.* (1946) obtained a similar rise in count when multiplying cultures of *K. pneumoniae* were exposed to sub-lethal concentrations of streptomycin, and in addition showed that surviving cells were more resistant to streptomycin.

Since chemical inactivation of streptomycin was not attempted in the present study, it is not known whether the results presented in Fig. 1 indicate that streptomycin had an irreversible effect on *Ps. syringae* at the higher concentrations. It is apparent nevertheless, that under certain conditions, *Ps. syringae* organisms which have been exposed to streptomycin are incapable of further division following dilution of the antibiotic to sub-inhibitory concentrations.

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SEARCH FOR ALTERNATIVE VECTORS OF THE YELLOW-LEAF DISEASE OF PHORMIUM

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(Received for publication, 2 April 1954)

Summary

Experiments testing five possible vector species of the yellow-leaf disease of *Phormium* are described. No further vector is incriminated although there is some suspicion in the case of the mealy-bug, *Trionymus diminutus* (Leonardi).

Introduction

Oliarus atkinsoni Myers has been incriminated as a vector of the yellow-leaf of *Phormium tenax* Forst. (Cumber, 1953a). Transmission by grafting and mechanical means has also been described (Boyce *et al.*, 1953). Tests to ascertain whether other insects are involved in the transmission of the disease have since been carried out, and results are described here. In all experiemnts seedlings of the variety known as "301" which is very susceptible, were used. In this paper the term "infection feed" refers to the feeding of a bug upon a plant (usually diseased) for the purpose of infecting the bug, whereas "test feed" refers to the feeding of the bug upon a plant (usually healthy) to test the effects of the bug on the plant.

Experimental Procedure

Tests with ***Trionymus diminutus*** *(Leonardi) (Hemiptera: Coccidae)*

The mealybug *T. diminutus* is common on *Phormium* throughout the Paiaka area. Its favourite habitat is the sheathing leaf bases where large colonies are found protected by masses of mealy substance. Under dry conditions the bug is occasionally found on roots and rhizome at, or slightly below, ground level. Small colonies may be found on aerial portions where the expanded blade becomes closed through leaf displacement.

The bugs used in experiments were collected from leaf bases. The process is a slow one since hasty removal damages mouthparts which penetrate some distance into the tissues. Collection has to be preceded by a gentle brushing.

Twelve-months-old seedlings raised in field beds, were used. These were transplanted to boxes 2 weeks before test feeding. Bugs were caged on a single leaf by means of 3 in. $\times$ $\frac{1}{2}$ in. glass tubes with cotton-wool stoppers, the tubes being supported with wires. Infection feeding where given, was on leaf of diseased pot plants from the 1950-51 trials with *O. atkinsoni*, using 6 in. $\times$ $1\frac{1}{4}$ in. glass tubes. Little mortality amongst bugs was observed. After test feeding the boxes of seedlings were kept in a glass-house until October 1952. At this stage there was some build-up of the bug population despite a careful removal of test bugs, and as spider mite was also causing damage, plants were placed in the open where they could receive the beneficial effects of rain and changing weather. There was a risk of field infection from this time onwards as no insectary space was available. Until the time of this removal from

the glasshouse, plants showed no typical symptoms of yellow-leaf such as have been induced with adults of *O. atkinsoni*, but the sudden die-back (Cumber, 1953b) was evident.

Details and results of experiments are shown in Table 1. Table 2 indicates the over-all percentages of affected plants in experiments involving test plants receiving bugs from diseased bushes, and control

TABLE 1.—EXPERIMENTS WITH *T. DIMINUTUS* (Set up 24.4.51—8.6.51)

Bug source plants	Stage of bugs	No. bugs per plant	No. plants	Infection feed (days)	Test feed (days)	Plants			Date of analysis
						Died during experiment	With typical *Oliarus*-induced symptoms	With sudden die-back symptoms	
Diseased	Nymphal	6	18	—	10	1	3	5	7.7.53
,,	Adult	2	20	—	35	1	0	6	26.8.52
,,	,,	2	11	—	10	2	1	5	7.7.53
,,	,,	1	43	—	28	7	2	7	7.7.53
,,	Various	4	15	—	10	8	0	6	7.7.53
,,	,,	6	36	—	14	20	1	11	7.7.53
Healthy	Nymphal	6	2	14 on diseased pot-plant	14	0	0	0	7.7.53
Controls	Adult	2	13	,,	14	3	0	2	7.7.53
no bugs	—	—	30	—	—	6	0	6	26.8.52
,,	—	—	20	—	—	5	1	9	7.7.53

TABLE 2.—OVER-ALL INFECTION PERCENTAGES IN TRIALS WITH *T. DIMINUTUS*

	Total bugs used	No. plants	Percentage of Plants		
			Died during experiment	With typical *Oliarus*-induced symptoms	With sudden die-back symptoms
Tests	489	143	27	5	28
Controls	—	50	22	2	30

plants receiving no bugs. Although the percentages of plants dying and showing typical *Oliarus*-induced symptoms are higher amongst test plants, any significance is open to question on account of the large number of affected control plants.

Experiments with Adults of ***Erythroneura zealandica*** *Myers (Hemipteras Typhlocybinae)*

The leaf-hopper E. *zaelandica* is very common on herbage associated with *Phormium* and occurs throughout the Paiaka area. The extent to which it feeds on *Phormium* under field conditions is not known, but bugs caged on seedlings fed readily. Day *et al.* (1952) have indicated that *Erythroneura* is primarily a parenchyma feeder, whereas the known vector, *O. atkinsoni,* feeds directly on the vasular stream.

The seedlings used and the methods of caging bugs for infection and test feeding were the same as those used in experiments with the mealy-bug. Bugs were collected from herbage at the base of the *Phormium* bushes in areas where disease was prevalent. Test plants were kept in the glass-house until their final analysis. In the later stages there was some build-up of mealy-bug and spider-mite populations, and sudden die-back symptoms were evident.

Details and results of experiments are shown in Table 3. Table 4 indicates the over-all percentages of affected plants amongst tests and controls. Although the percentage of dead plants plus plants with sudden die-back symptoms is higher in the tests, the large number of affected control plants makes no conclusions possible. No typical *Oliarus*-induced symptoms appeared.

Experiments with ***Oliarus oppositus*** *(Walk.) (Hemiptera: Cixidae)*

O. oppositus is found on a great variety of host plants over a considerable range in altitude and throughout the country; *O. atkinsoni,* on the other hand, has a limited number of host plants and appears to be restricted to some monocotyledons occupying the lower-lying districts of the North Island. In some areas adults of *O. oppositus* are more common than *O. atkinsoni* on *Phormium.* Nymphal and adult stages of the former are commonly found on *Carex* spp. in swamps.

TABLE 3. EXPERIMENTS WITH *E. ZEALANDICA* (SET UP 2—18.5.51; ANALYSED 29.10.52)

No. bugs per plant	No. plants	Infection feed (days)	Test feed (days)	Plants		
				Died during experiment	With typical *Oliarus*-induced symptoms	With sudden die-back symptoms
4	35	—	10	3	0	2
5	21	—	15	9	0	6
4	8	1, diseased plant	7	0	0	0
4	20	,,	14	9	0	0
4	28	3, diseased plant	15	9	0	6
1	30	1, ,,	4	6	0	4
4	12	3, healthy plant	13	3	0	0
Controls no bugs	80	—	—	7	0	19

Experiments were set up in 1951 and 1952. In the former year (A), 7-month-old seedlings were used, the bugs being caged by means of 4 in. × $\frac{3}{4}$ in. glass tubes with cotton-wool plugs. Roots were kept moist during test feeding after which plants were transferred to 6 in. pots. Infection feeding was carried out on diseased plants from 1950-51 trials with *O. atkinsoni,* using 6 in. × $1\frac{1}{4}$ in. glass tubes with cotton-wool stoppers. Bugs used were collected at Paiaka. In the 1952 experiment (B), $2\frac{1}{2}$-years-old seedlings established in pots were used. Bugs were caged on the central leaves by means of wire gauze tubes measuring 8 in. × $1\frac{1}{4}$ in. and plugged at the ends with cotton-wool. Bugs used were collected from diseased natural swamp areas near Plimmerton. Plants in all experiments were held in the insectary.

TABLE 4. OVER-ALL INFECTION PERCENTAGES IN TRIALS WITH *E. ZEALANDICA*

	Total bugs used	No. plants	Percentage of Plants		
			Died during experiment	With typical *Oliarus*-induced symptoms	With sudden die-back symptoms
Tests	547	154	25	0	12
Controls	—	80	9	0	24

Details and results are shown in Table 5. No symptoms typical of those inducted by *O. atkinsoni* were found, and sudden die-back was equally distributed in test and control plants.

TABLE 5. EXPERIMENTS WITH *O. OPPOSITUS*

Source of bugs	No. bugs per plant	No. plants	Infection feed (hr.)	Test feed (days)	Plants		
					Died during experiment	With typical symptoms *Oliarus*-induced	With sudden die-back symptoms
A. SET UP 27.11.—14.12.51, ANALYSED 5.6.53							
Diseased *Phormium*	5	8	—	10	0	0	3
Carex sp.	5	29	24	10	1	0	5
Controls, no bugs	—	37	—	—	0	0	10
B. SET UP 20.11.52, analysed 31.9.53.							
Diseased *Phormium*	10	18	—	7	0	0	2
Controls, no bugs	—	25	—	—	0	0	2

Experiments with Other Insects

During 1950 an attempt was made to transmit the yellow-leaf condition using adults of *Melampsalta cruentata* Fab. (Hemiptera: Cicadidae) and early stages of a mussel-scale. Both these insects are commonly found in diseased areas at Paiaka. Experiments were not extensive. The insetcts were transferred successfully from diseased bushes in the field to pot plants. No evidence for transmission was obtained.

DISCUSSION

Only in the case of the mealy-bug *T. diminutus* is there any suspicion of transmission, and this is not strong. There is no evidence that *O. oppositus* transmits the condition despite the earlier incrimination of the other New Zealand species, *O. atkinsoni*. The complication caused by the sudden die-back condition has been considerable. This appears to be more prevalent amongst experimental plants which ar set up for periods of more than one year.

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MOLYBDENUM CONTENT OF NELSON SOILS

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Summary

Various methods of extracting molybdenum from soils have been examined and results, obtained for a range of 17 soils, compared with the total molybdenum figures as determined by Perrin's method, and with the available molybdenum figures as determined by Grigg's method.

A survey of Nelson soils using acid digestion methods which extract a high proportion of the total molybdenum showed that many Nelson soils were comparatively low in molybdenum and that soils derived from the Moutere Gravels, the granite of the Motueka River System or the serpentine of the "Mineral Belt" were very low in molybdenum. The probability of molybdenum deficiency on these soils is suggested.

Comparatively high molybdenum figures have been found for the soils on the marble formation of the Takaka Hill.

Introduction

In 1950 when the work reported in this paper was commenced, molybdenum had been shown to be an essential element for higher plants[1] and molybdenum deficiency had been found in the field[2]. In New Zealand, Davies[3] had identified "Whiptail" of cauliflowers, known to occur in the Nelson district, as due to a deficiency of this element. A molybdenum survey of the main soil types of the Nelson district therefore seemed advisable. Since 1950, extensive pasture trials carried out by field officers of the New Zealand Department of Agriculture in collaboration with the Rukuhia Soil Research Station have shown that many areas, particularly in the South Island, respond to molybdenum, and Grigg[4] has been able to correlate these responses with a pH below 6.3 combined with a low level of "available" soil molybdenum as measured by extraction with an acid oxalate extractant of pH 3.3 Responses† have been obtained in the Nelson district on field plots established by both the Department of Agriculture and the Cawthorn Institute and the possible occurrence of widespread molybdenum-deficient areas has become apparent.

The data in this paper are concerned with the total or acid-soluble molybdenum and, except for certain selected soils, no attempt is made to determine the availability of molybdenum to the plant.

Experimental Procedure

Estimations of total molybdenum were made by the method of Perrin[5]. Owing to shortage of platinum and the inconvenience of using hydrofluoric acid for large numbers of analyses, other methods of extraction of molybdenum were tested, details of which are given below.

Three-Acid Mixture

Between two and three grammes of soil were digested with 10 c.c. of a mixture of sulphuric acid 4 parts, perchloric acid (20 per cent.)

*Officer of the Department of Scientific and Industrial Research.
†Private communication.

3 parts and water 1 part, to which 5 c.c. of nitric acid were added. Further nitric acid was used during digestion until all traces of organic matter had been destroyed. Incomplete destruction of organic matter at this stage produced interfering colours in the final solution. Boiling was continued till most of the perchloric acid had been driven off. For soils of very high organic matter the extraction was carried out on the ignited soil.

Hydrochloric Acid

The soil was ignited at 500°C. and digested in a boiling water-bath for 3 hr. with hydrochloric acid of sp. gr. 1.12 in the proportion of 1 g. soil to 5 - 10 c.c. HCl. For soils of low iron content 10 or more grammes of soil could be used. If more than 2 - 3 g. were used an ether extraction of the molybdenum was carried out as suggested by Perrin[5]. The final extract was digested with three-acid mixture to destroy the last traces of organic matter.

Sodium Hydoxide

Between 5 and 10 grammes of ignited soil (500°C.) were digested in a boiling water-bath for 3 hr. with 10 c.c. of $\frac{N}{5}$ NaOH for each gramme of soil. After filtration the extract was evaporated with the three-acid mixture and digested to destroy any traces of organic matter as for the HCl extracts.

Estimations of Molybdenum in the Extract

The method used was a modification of that of Perrin[6]. To the acid extract was added excess of ammonia, and the excess boiled off. For soils of high iron content it was found necessary to add 20 per cent H_2SO_4 to dissolve the iron precipitate (2 - 3 c.c. usually sufficient) and add ammonia till the iron precipitate just began to form again. The solution was evaporated to 20 c.c. and acidified with 4.5 c.c. HCl of sp. gr. 1.10. One c.c. of 5N $NaNO_3$ as recommended by Barshad[7] and 1 c.c. of a solution containing 2 mg. Fe per c.c. were added, followed by 4 c.c. of 20 per cent potassium thiocyanate. The ferric thiocyanate was decolourised by the addition of 1 c.c. of 50 per cent stannous choride or more if necessary. The molybdenum was extracted by shaking for one minute with 10 c.c. of iso-amyl alcohol saturated with stannous chloride and potassium thiocyanate as described by Dick and Bingley[8]. The amyl alcohol extract was washed with 0.2 per cent stannous choride solution, following the procedure of Dick and Bingley[8]. It was then run into centrifuge tubes and shaken with 0.5 c.c. 20 per cent stannous chloride solution. The extract was allowed to stand until the colour due to iron had faded (up to 1 hr.). It was then centrifuged and filtered and compared with standards prepared by the same procedure. Visual comparison was necessary owing to lack of a suitable photometer. For amounts in excess of 0.0006 mg. Mo in the soil extract, the method was sensitive to changes of 0.0002 mg. Mo.

It was found that some brands of ammonia produced an interfering yellow colour in the soil extracts. This yellow colour was not eliminated by distilling the ammonia.

Comparison of Methods of Extraction

Results obtained by Perrin's method for total molybdenum and by the procedures given above are set out for a range of soils in Table 1.

TABLE 1. MOLYBDENUM IN SOILS: COMPARISON OF METHODS OF EXTRACTION
(Mo expressed as p.p.m. of dry soil)

Lab No.	Locality	Parent Material	I Total Mo HF (Perrin)	II Mo soluble in H_2SO_4 + $HClO_4$ + HNO_3	III Mo soluble in HCl Sp. Gr. 1.12	IV Mo soluble in N/5 NaOH	V "Available" Mo (Grigg)	pH
C1A	Cook Islands	No information	9.7	9.9	5.5	1.8	0.41	8.0
C1649	Takaka Hill, Waimea County	Marble	3.2	3.2	3.0	1.5	0.19	5.9
1957	Banks Peninsula	Basalt	1.4	1.3	0.9	0.3	0.18	5.4
C1653	Takaka Hill, Waimea County	Marble	0.9	0.9	—	0.4	0.10	5.4
C2093	Buller Gorge	Granite	0.9	0.8	0.7	0.4	0.14	5.1
1491	Hawke's Bay	Mixed alluvium	0.9	0.9	0.9	0.5	0.63	5.8
C1823	Hamama Rd., Takaka County	Greywacke	0.6	0.6	0.5	0.3	0.11	5.6
C2197	Hope, Waimea County	Mixed alluvium	0.6	0.5	0.4	0.3	0.18	5.9
C1821	Orinoco, Waimea County	Granite-diorite	0.6	0.5	0.3	—	0.11	6.1
C2103	Murchison	Granite & greywacke alluvium	0.5	0.4	0.5	0.3	0.11	5.6
C1829	Takaka, Takaka County	Tertiary limestone	0.4	0.4	0.5	0.2	0.11	5.7
C1841	Mt. Heslington, Waimea County	Triassic shales	0.4	0.3	0.3	0.2	0.11	6.0
C2109	Kingsdale, N.S.W.	No information	0.3	Low*	0.24	0.05	0.03	—
C2111	Springton, S. Australia	,, ,,	0.4	Low	0.17	0.06	0.03	—
C2165	Kangaroo Is., ,,	,, ,,	0.3	Low	0.18	0.07	0.04	—
C2185	Stawell, Victoria	,, ,,	0.2	Low	0.05	0.04	0.02	—
C1815	Kaiteriteri, Waimea County	Granite	0.2	Low	0.12	0.04	0.03	4.8
C1804	Rosedale Hill, Waimea County	Moutere gravels	—	Low	0.08	—	0.02	4.5

*Note:—In column II "Low" is equivalent to less than 0.3 p.p.m.

These include four Australian soils which are known to respond to molybdenum. They were supplied by Dr. C. S. Piper of the Waite Institute, Adelaide.

A comparison is also made with "available" molybdenum estimated later by Grigg's method[4].

It will be seen from Table 1 that all methods of extraction distinguish between soils of high and low molybdenum content.

The three-acid mixture (Column II) gave results very close to the total figures. Owing to the amount of solid residue and the difficulty of evaporating a filtered extract because of bumping, it was not convenient to use this method for more than 2 - 3 g. of soil. The last six samples in Column II were too low in molybdenum to give a reliable figure using this amount of soil.

The HCl method (Column III) also extracted a high proportion of the total molybdenum in nearly all the soils tested. Sample C 1A, where the amount extracted was 5.5 p.p.m. compared with 9.7 for the total, had an exceptionally high iron content and increasing the proportion of HCl appeared to increase the amount of molybdenum extracted.

The Soda extraction (Column IV) dissolved a much smaller proportion of the total molybdenum. Tests with sample C1649 showed that the amount of molybdenum extracted from this soil was unaffected by increasing the strength of the soda solution up to at least 3N. Figures obtained by soda-extraction on unignited soils were much lower. A flocculent organic precipitate was formed which appeared to absorb molybdenum.

Grigg's acid oxalate solution (Column V) gave the lowest figures. The amount extracted by this reagent did not show such a definite relationship to the total molybdenum as in the case of the previous extractants. Certain soils, e.g. 1491, appeared to have a high proportion of "available" molybdenum.

All methods gave very low figures for the molybdenum-deficient Australian soils C2109, C2111, C2165 and C2185. The total molybdenum ranged from 0.4 to 0.2; the three-acid soluble molybdenum was less than 0.3 p.p.m., the HCl-soluble Mo was 0.18-0.05, the alkali-soluble molybdenum 0.07 or less, and the available, 0.04 or less. Two Nelson soils, C1815 and C1804, appear to be in the same range.

MOLYBDENUM SURVEY OF NELSON SOILS

For a preliminary survey of Nelson soils it was decided to use the three-acid extraction method for all samples giving a figure of 0.3 p.p.m. or more. The HCl-extraction method was used for soils of lower molybdenum content. Samples from the main soil types of the Nelson district, taken by officers of the Soil Bureau and the Cawthron Institute in connection with a soil survey of the South Island on a 4-mile-to-the-inch scale, have been examined for molybdenum. In addition, miscellaneous alluvial and other soils have been tested. The results are given in Table 2. The samples represent approximately the 0-6 in. depth of soil. pH values are not included for the alluvial soils, where lime may have been applied. Where molybdenum results for two depths have been combined, pH values are given for both depths, the first figure representing the top soil.

TABLE 2. ACID-SOLUBLE MOLYBDENUM CONTENT OF NELSON SOILS

(Expressed as p.p.m. of dry soil)

Lab. No.	Soil Type	Locality	Parent Material	Molybdenum		pH
				3-acid extraction	HCl extraction	
	(a) *Soils formed on Moutere Gravels*					
C1813-13A	Moutere Sandy Silt Loam	Cut Hill, Moutere	Moutere Gravels	Low*	0.07	4.9,4.9
C1803-04	Rosedale Sandy Silt Loam	Rosedale Hill	,, ,,	Low	0.08	4.8,4.5
C1805-06	Stanley Brook Sandy Loam	Sunday Valley	,, ,,	Low	—	5.5,5.6
C1807-08	Spooners Silt Loam	Spooners Range	,, ,,	Low	0.07†	5.3,5.5
	(b) *Soils formed on Granite*					
C1815	Kaiterteri Sandy Silt Loam	Kaiteriteri	Granite	Low	0.12	4.8
C1819-20	Pokororo Sandy Loam	Pokororo	,,	Low	0.04	5.5,5.6
C2212	Glenhope Silt Loam	Hop Valley	,,	Low	—	4.9
C2093	Kanieri Sandy Loam	Buller Gorge	,,	0.8	—	5.1
C1821	Orinoco Silt Loam	Ngatimoti	Granite-diorite	0.5		6.1
C1827	Ligar Sandy Loam	Ligar Bay	Basic granite	0.6		5.5
	(c) *Soils formed on Marble, Limestone or Calcareous Deposits*					
C2208	Pikikiruna Silt Loam	East Takaka, 1000 ft.	Ordovician marble	1.2	—	5.5
C1649	,, Sandy Loam	Summit, Takaka Hill	,, ,,	3.2	—	5.9
C1845	,, ,, ,,	Near Summit, Takaka Hill	,, ,,	2.2	—	5.7
C1653	,, ,, ,,	East side, Takaka Hill	,, ,,	0.9	—	5.4
C1829-29A	Rototai Silt Loam	Takaka	Teritary limestone	0.4	—	5.7,5.9
C2091-92	Tutaki Silt Loam	Near junction Mangles and Tutaki Rivers	Calcareous mudstone	0.7	—	5.5,5.5
C2095	Kongahu Heavy Silt Loam	Westport—Karamea Rd.	,, ,,	0.8	—	4.2
C2101-2	Anatori Silt Loam	Near mouth, Anatori River	Fine calareous sandstone	1.0	—	7.7,7.2
	(d) *Soils on other geological formations*					
C2206	Otere Clay Loam	Bainham	Tertiary mudstone	0.6	—	4.5
C1833-34	Whangamoa Silt Loam	Whangamoa Saddle	Maitai shales	0.4	—	5.9,5.6
C1814	Heslington Silt Loam	Mt. Heslington	Triassic shales	0.3	—	6.0
C1843-44	Tadmor Silt Loam	Tadmor Hill	Tertiary sandstone	0.5	—	5.3,5.5
C2210A-10B	Haupiri Silt Loam	Takaka Valley	Siliceous greywacke	1.2	—	3.5,3.8
C1835-36	Wakatu Silt Loam	Port Hills, Nelson	Miocene gravels	0.5	—	5.7,5.9
C1615	,, ,, ,,	Wakatu, Nelson	,, ,,	0.4	—	6.1

C1817	Brooklyn Silt Loam	Little Sydney Valley	Gabbro	Low	0.15	5.3
C1847	Dun Silt Loam	Lee Valley	Serpentine	Low	0.10	7.4
C2213A	Kawatiri Silt Loam	Lamb Valley	Granodiorite and diorites	0.5	—	5.2
C2337	Otu Silt Loam	Mackays Bluff	Diorite	0.8	—	5.6
C2335	Atawhai Silt Loam	Above Todd's Valley	Brook St. igenous	0.4	—	6.1
C2336	„ „ „	Sugar Loaf, Brook Valley	„ „ „	0.5	—	6.0
(e) *Alluvial soils of recent origin*						
3183	Motupiko Loam	Lower Moutere, Waimea County	Mainly Moutere gravels	Low	0.15	
C1419	„ „	Glen Rae, Tapawera, Waimea County	Moutere gravels and tertiary mudstone	0.6	—	
C191	Riwaka	Pearce Valley, Waimea County	Granite with some material from Mt. Arthur Series	Low	0.13	
C69	„	Baton Valley, Waimea County	„ „ „ „	Low	0.06	
C173	„	Graham Valley, Waimea County	Mainly Mt. Arthur Series with some granite	0.4	—	
C2097	Karamea Sandy Silt Loam	Karamea River, West Coast	Granite and tertiary sediments	1.5	—	
C2099	Oparara Silt Loam	Coastal terrace S.E. of Karamea River, West Coast	Granite greywacke and tertiary sediments	0.8	—	
C2103	Ahaura Silt Loam	Murchison	Granite and greywacke	0.4	—	
C2207	Puramahoi Silt Loam	Puramahoi, Takaka County	Granite quartzites and limestone	2.7	—	
C1823	Hamama Silt Loam	Hamama Rd., Takaka County	Greywacke	0.6	—	
C2209	Kotinga Fine Sandy Loam	Kotinga Rd., Takaka County	Siliceous greywacke	0.7	-	
C2217	Graigieburn Silt Loam	Buller Valley	Greywacke	0.4	—	
C1851-52	Howard Silt Loam	Howard Valley, Buller County	Morainic greywacke and Rotoroa igneous	0.9	—	
C1825	Rameka Silt Loam	Terrace above Rameka Creek, Takaka County	Mixed, including gabbro	0.5	—	
C1381	Tapawera Loam	Mararewa, Waimea County	Partly serpentine	Low	0.10	
C1535	Nelson Loam	Cawthorn Institute, Nelson	Maitai slates, Brook St. igneous and serpentine	0.4	—	
C2197	Ranzau Silt Loam	Hope, Waimea County	Serpentine and Maitai slates	0.5	—	
(f) *Pakihi soils*						
2059A-59B		Westport	Granite	0.4		
1499A-99B		Collingwood	„	0.4		

*With the 3-acid extraction "Low" is equivalent to less than 0.3 p.p.m.
†Figure for C1807 (0-3 m.) only.

Discussion

It may be assumed from the results in Table 1 that the acid extractions have removed a high proportion of the total molybdenum. Many Nelson soils therefore appear to have a low molybdenum content. Robinson and Alexander[9], from an examination of total molybdenum figures from a number of sources, suggest 2.5 p.p.m. as an average figure for soils. Of the Nelson soils examined (Table 2), few have a higher content of acid-soluble Mo than 1.0 p.p.m. and certain areas have less than 0.2 p.p.m. In the latter class fall the extensive Moutere Gravel soils and the granite soils of the Motueka River System (Table 2 (a) and (b)). Thus Samples C1813—13A, C1803—04, C1805—06 and C1807—08 from different soil types of the Moutere formation, all had less than 0.3 p.p.m., and where tested by the HCl extraction, gave figures as low as 0.07 to 0.08 p.p.m. Alluvial soils derived mostly from Moutere Gravels might also be expected to have a very low molybdenum content such as is found in 3183 (Table 2 (e)). In Sample C1419, the Moutere material has been considerably modified by the presence of tertiary mudstone sediments which have raised the acid-soluble Mo to a much higher figure.

The granite soils C1815, C1819—20, and C2212 (Table 2 (b)) have acid-soluble molybdenum comparable in amount with the low molybdenum content of the Moutere Gravel soils. The alluvial granite-derived soils of the valleys of the Motueka River System form an important horticultural area. Where these alluvial soils are predominately granitic in origin, low figures were found, e.g., Samples C191 and C69 (Table 2 (e)). Appreciable quantities of material from the Mt. Arthur Series appeared to raise the molybdenum content (Sample C173). Certain soils formed on granite-diorite or basic granite, viz. C1821 and C1827 (Table 2 (b)) were found to have an acid-soluble molybdenum content of 0.5 p.p.m. or more. The granite-derived Kanieri Sandy Loam form the Buller Gorge (C2093), gave a comparatively high figure for molybdenum compared with the granite soils of the Motueka River Valley. No exceptionally low molybdenum contents were found in alluvial soils of the northern West Coast derived from granite mixed with other sediments (C2097, C2099 and C2103, Table 2 (e)).

Comparatively high acid-soluble molybdenum figures were associated with the Pikikiruna Silt or Sandy Loam on the marble formation of the Takaka hills. This soil varied in molybdenum content from place to place but gave a figure as high as 3.2 p.p.m. for one locality sampled (C1649). The soil in this place was about 15 in. deep and showed a high molybdenum content at all depths. The B horizon was red-brown in colour similar to C1845. Sample C1653, with a lower molybdenum content, showed less weathering than C1649.

The Dun Silt Loam formed on serpentine (C1847, Table 2 (d)) and the Tapawera Loam containing a large proportion of serpentine alluvium (C1381, Table 2 (e)) both had a low content of acid-soluble molybdenum, as did also a soil found on gabbro material in the vicinity of the low-molybdenum granite area of the Motueka River System (C1817).

An alluvial soil of comparatively high molybdenum content (2.7 p.p.m.) was found at Puramahoi (C2207), and figures of 1.0 p.p.m. to 1.5 p.p.m. were given by the Anatori Silt Loam on calcareous sandstone (C2101—2, Table 2 (c)), the Haupiri Silt Loam on siliceous

greywacke (C2210A—10B, Table 2 (d)) and the Karamea Sandy Silt Loam formed from alluvium of granite and tertiary sediments (C2097, Table 2 (e)).

The two Pakihi soils both contained 0.4 p.p.m. of acid-soluble molybdenum, a comparatively low figure, but higher than might have been expected for this type of soil, where most trace elements tend to be low owing to excessive leaching.

The results indicate that molybdenum responses should be obtained on soils of the Moutere Gravels, on the granite derived soils of the Motueka River System, on soils containing a high proportion of serpentine material and possibly on soils derived from the gabbro of the Little Sydney Valley area. It will be seen in Table 1, Column V that samples of Moutere- and granite-derived soils gave 0.02 p.p.m. and 0.03 p.p.m. of molybdenum by Grigg's method for available molybdenum[4], and were comparable with the Australian soils C2109, C2111, C2165 and C2185, which have been found by Australian workers to respond to molybdenum. Field trials by the Department of Agriculture and the Cawthron Institute have already given indications of molybdenum response* on soils derived from the Moutere Gravels.

Grigg[4] reports molybdenum responses in most of the topdressing trials where available molybdenum was below 0.14 p.p.m. provided the pH was less than 6.3. Using Grigg's method, Walsh, Keenan and O'Moore[10] found molybdenum deficiency in soils of pH 4.9 to 5.5 with "available" molybdenum of 0.04 to 0.12 p.p.m. They found comparatively high molybdenum present in the herbage where the "available" molybdenum was in the range 0.2 to 0.7 p.p.m. and the pH, 6.8 to 7.8 The figures in Table 1 suggest that Nelson soils higher in molybdenum than the Moutere-, granite-, or serpentine-derived soils may respond to molybdenum unless heavily limed. Thus some Nelson soils in Table 1 with acid-soluble molybdenum between 0.3 and 0.9 p.p.m. have less "available" molybdenum than 0.12 p.p.m. The possibility of excess uptake of molybdenum of the plant with heavy liming on soil types such as the Pikikiruna Loam where the molybdenum content is high, is also suggested.

*Private communication.

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NOTE ON MOLYBDENUM RESPONSE ON PEAS IN NELSON

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Experiments have been carried out in Nelson during the latter part of 1953 with molybdenum and its effect on peas for vining purposes.

Sodium molybdate has been applied by dusting on the seed, mixed with superphosphate, as a pre-emergence spray and by spraying at emergence. These experiments have been carried out on a variety of soil types but the most definite response was obtained on a Motupiko silt loam. Here molybdenum was applied at 2 oz. per acre in two trials, one as a pre-emergence spray and the other when the Greenfeast peas were 2 in. high. Results were not apparent until the peas were two months in the ground.

There was no noticeable difference in the final result between the two spraying methods. In both trials the treated peas were of a healthy green colour and only slightly taller than the untreated ones which looked unthrifty with pale green to yellow leaves. Treated peas had pinkish nodules which were larger than the greyish nodules of untreated peas. This observation has been previously recorded overseas. Bobko and Savvina (1940) reported a favourable effect of molybdenum in the nodulation of peas. According to Virtanen and Laine (1946) the pink colour of the nodules is attributable to haemoglobin and the grey colour to methaemoglobin. The nitrogen efficiency of the nodules is related to their content of haemoglobin and methaemoglobin. If the colour is pink the activity is high; if grey the activity is lower and the balance lies too much on the side of methaemoglobin. E. G. Mulder (1948) carried out experiments on the place of molybdenum in symbiotic nitrogen fixation. With peas in culture solution he found that nitrogen fixation of the nodules was greatly curtailed in the absence of molybdenum. He observed that molybdenum appears to act as a catalyst in nitrogen fixation. G. C. Wade (1952) obtained a reponse to molybdenum on Greenfeast peas and observed that peas without molybdenum showed symptoms of nitrogen deficiency accompanied by few grey nodules. Peas treated with molybdenum were green and healthy with many creamy coloured nodules. Anderson, A. J. *et al.* (1946) showed the effect of molybdenum on legumes was attributable to more effective nitrogen fixation.

It was further observed that treated peas were more resistant to disease and the collar rot group lesions were smaller than on the untreated ones. The treated peas "held" better than the untreated ones, the latter maturing about two days ahead of the former and going off quickly. The treated peas yielded twice as heavily as the untreated ones.

Responses were not obtained on other pea growing areas in Nelson presumably due to a sufficient supply of available molybdenum or to the presence of sufficient molybdenum in the seed. (Johnson *et al.*, 1952)

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PASTURE ESTABLISHMENT STUDIES

III. BARLEY AS A COVER CROP IN ESTABLISHING PASTURES FOR THE PRODUCTION OF LATE AUTUMN AND WINTER GREEN-FEED

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Summary

The effect of barley as a cover crop for winter green-feed, on development, growth and yield of sown and unsown species in autumn sown pastures was investigated. Short rotation ryegrass, and red and white clover were included in the seeds mixtures and the ryegrass was sown at two rates, 15lb. and 40 lb. per acre, respectively.

Mixtures were also sown without barley.

The effects of ryegrass seedling rate were similar to those reported in previous experiments, Parts I and II.

A significant increase in total yield was obtained over the winter period from pastures containing barley. Ryegrass yields over this period were significantly depressed by the barley.

During the spring total yields and ryegrass yields decreased significantly where barley was sown, but clover yields increased.

Yields obtained over the summer period did not differ significantly.

The results are discussed in relation to competition for light and soil nitrogen.

Introduction

The inclusion of a cereal as a cover or nurse crop or for the production of green-feed, in pasture mixtures, has been extensively practised, but in only a few instances are the results of quantitative determinations reported. Moreover, in most investigations (Stapledon *et. al.*, 1925; Davies, 1927; Davies, 1928), the cover crop was spring sown at relatively high rates (3-4 bushels per acre) and first cuts were not made until the cereal was at an advanced stage of growth, either when the grain was in the "milk" stage or fully ripe. Little work appears to have been done on the New Zealand practice of autumn sowing a cereal at 1-2 bushels per acre with a standard pasture mixture, with the sole aim of producing extra winter feed.

The British results generally show that reduced pasture yields are associated with the use of a cereal nurse crop, and that establishment and subsequent growth of the pasture species are depressed. When ryegrass is included in the mixture, however, the nurse crop assists in checking its relatively fast seedling growth with consequent better development of the other constituents of the mixture, particularly of the legumes.

The previous experiments, reported in Parts I and II, showed that short rotation ryegrass, sown at a high rate, depressed the clovers, whereas light sowings, although favouring clover growth, resulted in diminished herbage production during the first winter. A consideration of the growth habits of barley and short rotation ryegrass suggested that if barley were sown at a light rate it might be less aggressive than the ryegrass, and enable high winter herbage production to be achieved without serious depression of clover seedlings. The experiment was designed, therefore, to determine the effect of the inclusion of barley in pastures of short rotation ryegrass, red clover and white clover.

Experimental Design and Procedure

The experimental area was at Palmerston North on Manawatu silt loam. In March 1952 it was ploughed out of spaced plants of ryegrass species that had been fertilised with superphosphate and sulphate of ammonia and grazed by sheep. The fertility of the area was very similar to that used for the experiment described in Part I.

During seed-bed preparation 3 cwt. of superphosphate per acre was applied, and on 1 April 1952 the five different seeds mixtures shown in the table below were sown.

SEED MIXTURES IN LB. OF VIABLE SEED PER ACRE

Species	Mixture				
	1	2	3	4	5
Barley			50	50	50
Short Rotation Ryegrass	15	40	15	40	10
Broad Red Clover	4	4	4	4	4
White Clover	3	3	3	3	3
Timothy					5

All seeds were of pedigree origin.

Each plot was 1 ch. $\times$ $\frac{1}{2}$ ch. and there were three randomised replications. The fifth mixture was included for observations on the establishment of timothy, but is included in all analyses.

For Treatments 3, 4, and 5 the barley was hand sown, disced-in and rolled with a Cambridge roller. The plots sown with Mixtures 1 and 2 were also disced and rolled to ensure uniformity in seed-bed preparation.

Apart from this, the procedures with respect to sowing, fencing, grazing, and measurement of yields were the same as those already described in Part II.

For the first three grazings, plots were grazed when the growth of barley was at a height of 9-12 in. The herbage height in Treatment 2 for the first grazing was about 3-4 in., and for Treatment 1, 2-3 in. At the 2nd and 3rd grazings the herbage height in these treatments was about 3-4 in. Subsequent grazings were carried out when the herbage height in all treatments was about 6in. (c.f. Part I).

Seedling counts were made approximately one month after sowing, and one subsequent count of surviving clover plants was made after the second grazing by methods described in Part II. Two determinations of ryegrass tiller populations were made by cutting to ground level, the herbage within a square foot quadrat, and counting the tillers. The first sample was made immediately before the first grazing, and the second, just prior to the third grazing.

The experiment was concluded on 10 April 1953.

Results

Herbage Production and Species Yields

Yields are presented for three periods. The first period comprises late autumn and winter, during which barley and ryegrass were the

dominant components of the establishing pastures; the second comprises spring and early summer when the influence of clover on total herbage and ryegrass yields became effective; and the third comprises summer and early autumn during which clover yields approached ryegrass yields. Finally, the results for the whole experimental period are presented.

For each period total and species yields from sown and unsown species are shown. Statistical analysis of total herbage, ryegrass and clover (including both red and white clover) yields were made, and the results obtained from the analysis of variance are shown in a complementary table to the table of means.

Results are expressed throughout as pounds of Dry Matter per acre.

First Period (1/4/52 - 8/8/52)

Table 1 shows total and species yields for the first period of growth.

The following deductions are made from Table 1:

The Effect of Cover Crop on Yields: There was a significant increase in total yield for the treatments in which barley was included. For ryegrass yields, however, the results of the "F" test showed a highly significant decrease for the cover crop treatments. Clover yields and yields of unsown species (although small in comparison to total yields) also show a decrease.

Seeding Rate: There were highly significant increases in both total and ryegrass yields from the heavier seeding rate.

Seeding Rate x Barley Interaction: The difference obtained from the cover crop comparison were not significantly modified by the ryegrass seeding rate.

Second Period (8/8/52 - 6/1/53)

Table 2 shows total and species yields for the second period of growth.

The following deductions are made from Table 2:

The Effect of Cover Crop on Yields: From the cover crop treatments there were significant decreases in total yield and in ryegrass yield and a significant increase in clover yield.

Seeding Rate: Total herbage yields did not differ significantly for the two ryegrass seeding rates, but at the high seeding rate ryegrass yields were significantly lower, and white clover yields significantly higher, than at the low rate.

Seeding Rate x Barley Interaction: The differences obtained from the cover crop comparison were not significantly modified by ryegrass seeding rate.

Third Period (6/1/53 - 10/4/53)

Table 3 shows total and species yields for the third period of growth.

Deductions from Table 3 are:

The Effect of Cover Crop on Yields: No significant differences in yields were obtained.

Seeding Rate: There were no significant differences in yields.

Seeding Rate x Barley Interaction: No significant interaction.

Total Period (1/4/52 - 10/4/53)

Table 4 shows total and species yields for the total period.

Deductions from Table 4 are:

TABLE 1. TOTAL AND SPECIES YIELDS FROM 1/4/52 to 8/8/52

	Mixture		Total Yields (lb. D.M./ac.)	Species Yields (lb. D.M./ac.)						
	Barley (lb./ac.)	Ryegrass Rate (lb./ac.)		Barley	Ryegrass	Timothy	Clover			Unsown Species
							Red	White	Total	
1	—	15	900	—	740	—	20	20	40	120
2	—	40	1300	—	1205	—	10	10	20	75
3	50	15	1180	920	210	—	—	5	5	45
4	50	40	1390	915	440	—	—	5	5	30
5	50	10	1130	915	185	—	—	5	5	25
1, 2	—		1100		975					
3, 4	50		1285		325					
1, 3		15	1040		475					
2, 4		40	1345		825					

ANALYSES OF VARIANCE FOR TOTAL AND RYEGRASS D.M. YIELDS SHOWN IN TABLE 1

Source of Variation	d.f.	F Reqd. 5% (1%)	Ryegrass		Total Production	
			Mean Sq.	F	Mean Sq.	F
Blocks	2					
Barley v No Barley	1	5.32 (11.26)	1238,419	46.00**	103,045	4.56(*)
15 lb./ac. v 40 lb./ac.	1	„	351,234	13.05**	276,033	12.21**
Rate x Barley Interaction	1	„	44,287	1.65†	30,000	1.33†
Mixture 5 v Others	1	„	552,480	19.41**	8,640	0.38†
Residual	8		26,921		22,610	
Coefficient of Variation			7.0%		12.7%	

** difference significant at the 1% level of probability
* „ „ „ „ 5% „ „ „
(*) almost significant at the 5% level of probability
† difference not significant

The Effect of Cover Crop on Yields: There were significant decreases in both total herbage and ryegrass yields from the treatments in which barley was included. Clover yields, however, did not differ significantly.

Seeding Rate: There were no significant differences in yields.

Seeding Rate x Barley Interaction: There was no evidence of an interaction between seeding rate and barley.

TABLE 2. TOTAL AND SPECIES YIELDS FROM 8/8/52 to 6/1/53

	Mixture		Total Yields (lb. D.M./ac.)	Species Yields (lb. D.M./ac.)						
	Barley (lb./ac.)	Ryegrass Rate (lb./ac.)		Barley	Ryegrass	Timothy	Clover			Unsown Species
							Red	White	Total	
1	—	15	10,640	—	9,480	—	370	440	810	350
2	—	40	9,920	—	8,540	—	650	550	1,200	180
3	50	15	9,820	70	8,220	—	450	720	1,170	360
4	50	40	8,620	50	6,940	—	640	770	1,410	220
5	50	10	9,400	160	6,970	190	890	800	1,690	390
1, 2	—		10,280		9,010				1,005	
3, 4	50		9,220		7,580				1,290	
1, 3		15	10,230		8,850				990	
2, 4		40	9,270		7,740				1,305	

ANALYSES OF VARIANCE FOR TOTAL, RYEGRASS, AND TOTAL CLOVER D.M. YIELDS SHOWN IN TABLE 2

Source of Variation	d.f.	F Reqd. 5% (1%)	Ryegrass		Clover		Total Production	
			Mean Sq.	F	Mean Sq.	F	Mean Sq.	F
Blocks	2							
Barley v No Barley	1	5.59 (12.25)	6,777,027	9.62*	208,297	4.95(*)	4,020,576	7.87
15 lb./ac. v 40 lb./ac.	1	„	3,230,256	4.59(*)	342,394	8.13*	2,241,216	4.39†
Rate x Barley Interaction	1	„	23,232	0.03†	9,020	0.21†	57,963	0.11†
Mixture 5 v Others	1	„	4,006,234	5.69*	725,780	17.24**	204,400	0.40†
Residual	7		704,204		42,106		510,867	
Coefficient of Variation			10.4%		16.3%		7.4%	

** difference significant at the 1% level of probability
* „ „ „ „ 5% „ „ „
(*) almost significant at the 5% level of probability
† difference not significant

Figure I shows the comparative yields at successive cuts of the two extreme treatments compared in this experiment. The comparison is for Treatments 1 and 4.

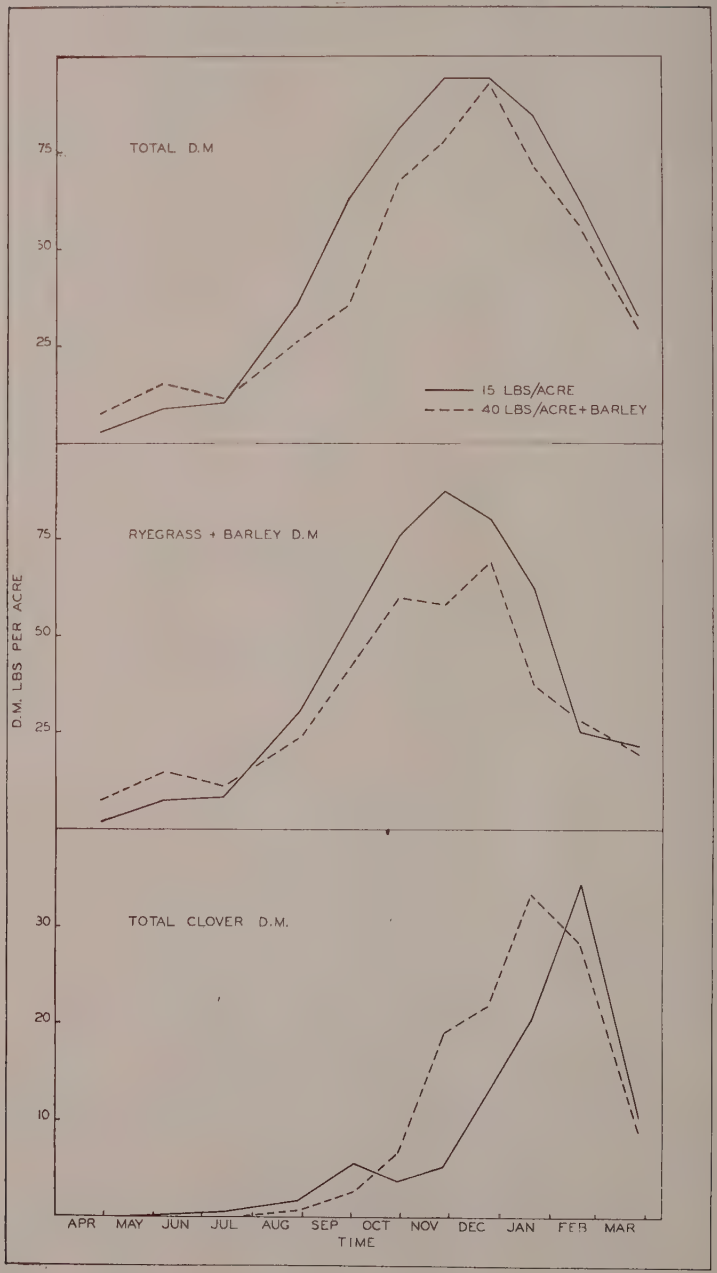

Fig 1.—Herbage Production (as dry matter increment per day) from the 15 lb. per acre ryegrass sowings and the 40 lb. per acre ryegrass sowings plus barley for the total period of measurement.

TABLE 3. TOTAL AND SPECIES YIELDS FROM 6/1/53 to 10/4/53

	Mixture		Total Yields (lb. D.M./ac.)	Species Yields (lb. D.M./ac.)						
	Barley (lb./ac.)	Ryegrass Rate (lb./ac.)		Barley	Ryegrass	Timothy	Clover			Unsown Species
							Red	White	Total	
1	—	15	5,520	—	3,300	—	690	1,390	2,080	140
2	—	40	4,360	—	2,540	—	680	1,070	1,750	70
3	50	15	4,560	—	3,280	—	430	800	1,230	50
4	50	40	4,860	—	2,620	—	770	1,440	2,210	30
5	50	10	4,880	—	2,760	240	690	1,150	1,840	40
1, 2	—		4,940		2,920				1,915	
3, 4	50		4,710		2,950				1,720	
1, 3		15	5,040		3,290				1,655	
2, 4		40	4,610		2,580				1,980	

ANALYSES OF VARIANCE FOR TOTAL, RYEGRASS, AND TOTAL CLOVER D.M. YIELDS SHOWN IN TABLE 3

Source of Variation	d.f.	F Reqd. 5% (1%)	Ryegrass		Clover		Total Production	
			Mean Sq.	F	Mean Sq.	F	Mean Sq.	F
Blocks	2							
Barley v No Barley	1	5.59 (12.25)	11,781	0.03†	172,320	0.55†	275,730	0.61†
15 lb./ac. v 40 lb./ac.	1	„	1,601,621	3.44†	375,948	1.21†	379,852	0.84†
Rate x Barley Interaction	1	„	1,776	0.00†	1,399,467	4.50†	1,914,404	4.21†
Mixture 5 v Others	1	„	92,984	0.20†	1,421	0.00†	18,691	0.04†
Residual	7		465,640		311,374		454,291	
Coefficient of Variation			23.5%		10.4%		13.9%	

† difference not significant

It should be noted that each point on the graphs has been obtained by dividing the weight of herbage produced at each grazing by the number of days of growth between successive grazings. It is realised that this procedure produces an arbitrary rate-of-growth figure and assumes that rate of pasture growth is constant between grazings. More detailed and precise rate of growth studies on such pastures are now being carried out under field conditions at the Grasslands Division.

TABLE 4. TOTAL AND SPECIES YIELDS FROM 1/4/52 TO 10/4/53

	Mixture		Total Yields (lb. D.M./ac.)	Species Yields (lb. D.M./ac.)						
	Barley (lb./ac.)	Ryegrass Rate (lb./ac.)		Barley	Ryegrass	Timothy	Clover Red	Clover White	Clover Total	Unsown Species
1	—	15	17,060	—	13,520	—	1,080	1,850	2,930	610
2	—	40	15,580	—	12,285	—	1,340	1,630	2,970	325
3	50	15	15,560	990	11,710	—	880	1,525	2,405	455
4	50	40	14,870	965	10,000	—	1,410	2,215	3,625	280
5	50	10	15,410	1,075	9,915	430	1,580	1,955	3,535	455
1, 2	—		16,320		12,900				2,950	
3, 4	50		15,215		10,855				3.015	
1, 3		15	16,310		12,615				2,665	
2, 4		40	15,225		11,140				3,300	

ANALYSES OF VARIANCE FOR TOTAL, RYEGRASS, AND TOTAL CLOVER D.M. YIELDS SHOWN IN TABLE 4

Source of Variation	d.f.	F Reqd. 5% (1%)	Ryegrass		Clover		Total Production	
			Mean Sq.	F	Mean Sq.	F	Mean Sq.	F
Blocks	2							
Barley v No Barley	1	5.32 (11.26)	13,014,584	6.71*		0.00†	6,843,320	5.80*
15 lb./ac. v 40 lb./ac.	1	„	6,101,854	3.15†	1,385,161	2.98†	1,395,372	1.18†
Rate x Barley Interaction	1	„	102,860	0.05†	1,220,494	2.63†	1,894,485	1.61†
Mixture 5 v Others	1	„	9,176,770	4.73(*)	631,494	1.36†	5,275	0.00†
Residual	8		1,938,419		464,785		1,180,316	
Coefficient of Variation			12.1%		7.4%		6.9%	

* difference significant at the 5% level of probability
(*) almost significant at the 5% level of probability
† difference not significant

Percentage Emergence and Tiller Development of Short Rotation Ryegrass

Table 5 shows initial ryegrass emergence counts given both as number of emerged seedlings per unit area and percentage emergence of viable seeds sown for each of the five treatments. Also shown are the

TABLE 5. RYEGRASS EMERGENCE, TILLER NUMBERS PER UNIT AREA AND TILLERS PER EMERGED SEEDLING

Mixture	15 lb./ac.	40 lb./ac.	15 lb./ac. + Barley	40 lb./ac. + Barley	10 lb./ac. + Barley	Results of F test	d.05 (where F sig.)
Viable Seeds Sown per sq. ft. (1/4/52)	71.7	191.2	71.7	191.2	47.8		
Emerged Seedlings per sq. ft. (30/4/52)	44.4	106.2	46.2	109.2	30.4	Not analysed	
Percentage Emergence of Viable Seeds Sown	61.9	55.5	64.4	57.1	63.6	*	8.46
Number of Tillers per sq. ft. (26/5/52)	110	323	112	206		**	69.2
Tillers per Emerged Seedling (26/5/52)	2.47	2.94	2.94	1.84		†	
Number of Tillers per sq. ft. (12/8/52)	312	347	173	265		**	50.1
Tillers per Emerged Seedlings (12/8/52)	7.10	3.20	3.75	2.35		(*)	3.64

d.05 difference detectable at 5% level
** significant at the 1% level
* significant at the 5% level
(*) almost significant at the 5% level
† differences not significant

results of two subsequent determinations of tiller numbers per unit area for the four treatments in which both seeding rate and cover-crop effects were compared, together with numbers of tillers produced per emerged seedling. These results were obtained by dividing the number of tillers at each count by the number of emerged seedlings and consequently do not take into account seedling or tiller death. The results of the analyses of variance for the different determinations are also shown.

Deductions from Table 5 are:

Percentage Emergence: For the 15 lb. per acre ryegrass sowing the mean percentage emergence was 63.2 per cent with 56.3 per cent for the 40 lb. per acre sowing (difference significant at the 5 per cent level). Although not shown by Table 5, the difference in percentage emergence was due to seeding rate and was not affected by the cover crop.

**Number of Tillers per Unit Area:* (i) *Count on 26/5/52:*

Ryegrass tiller populations were significantly higher where the rate of ryegrass seeding was heavy. At the lower seeding rate the addition of barley did not influence tiller development, but at the higher seeding rate tiller development was depressed significantly. The test of this interaction gave a significant "F" value of 6.28 for 1 and 27 degrees of freedom.

*The determinations for both numbers of tillers per unit area, and tillers per emerged seedling were performed for only two of the three replications and consequently the form of the analyses of variance applied restrict the conclusions to the block used only, and will not allow generalisation beyond this area.

(ii) *Count on 12/8/52:* There were highly significant differences for numbers of tillers per unit area. Although not shown by Table 5, the results of "F" tests gave highly significant differences for both seeding-rate and cover-crop means with no evidence of an interaction. For the seeding-rate comparison the number of tillers per unit area was significantly lower in the 15 lb. per acre ryegrass sowing, and for the cover-crop comparison tiller numbers were significantly depressed by the cover crop.

**Tillers per Emerged Seedling:* (i) For the first determination of tillers produced per emerged seedling, the differences between individual treatments did not reach significance level.

(ii) For the second determination, the mean for the 15 lb. per acre ryegrass sowing, without barley, was significantly higher than either of the means of the 40-lb. sowings with and without barley, and almost significantly higher than the mean for the 15-lb. sowing with barley. However, the differences between the means of these last three treatments did not differ significantly. The results of the "F" test also showed

TABLE 6. EMERGENCE COUNTS OF RED AND WHITE CLOVER (as number of emerged seedlings per sq. ft. and as percentage emergence of viable seeds sown) TOGETHER WITH PERCENTAGE SURVIVAL OF EMERGED SEEDLINGS ON THE DATE SHOWN

	Mixture	15 lb./ac.	40 lb./ac.	15 lb./ac. + Barley	40 lb./ac. + Barley	10 lb./ac. + Barley	Results of F test	d.05 (where F sig.)
Red Clover	Viable Seeds Sown per sq. ft. (1/4/52)	17.2	17.2	17.2	17.2	17.2		
	Number of Emerged Seedlings per sq. ft. (7/5/52)	11.75	11.2	12.2	12.4	11.6	†	
	Percentage Emergence of Viable Seeds Sown	68.3	65.1	70.9	72.1	67.4	†	
	Percentage Survival of Emerged Seedlings (24/6/52)	81.0	55.0	59.5	56.5	71.5	†	
White Clover	Viable Seeds Sown per sq. ft. (1/4/52)	45.1	45.1	45.1	45.1	45.1		
	Number of Emerged Seedlings per sq. ft. (7/5/52)	28.25	32.8	30.9	34.8	33.75	†	
	Percentage Emergence of Viable Seeds Sown	62.6	72.7	68.5	77.2	74.8	†	
	Percentage Survival of Emerged Seedlings (24/6/52)	94.5	64.0	61.5	58.5	63.5	**	18.01

d.05 difference detectable at the 5% level
** significant at the 1% level of probability
† differences not significant

that the increase in number of tillers per emerged seedling in the 15-lb. sowing without barley was due to the lower seeding rate rather than to the cover crop.

Percentage Emergence and Plant Survival of Red and White Clover

Table 6 shows emergence counts of red and white clover both as number of seedlings per sq. ft. and as percentages of viable seeds sown, together with one subsequent determination of surviving red and white clover plants. The latter determination is shown as percentage survival of emerged seedlings. Results of the analyses of variance for each count are included.

Deductions from Table 6 are:

Percentage Emergence: The percentage emergence of red and white clover in the various treatments did not differ significantly.

Percentage Survival of Emerged Seedlings: (i) *Red Clover:* The differences between treatment means did not reach significance level for any of the comparisons made. The mean for the 15 lb. ryegrass sowing without barley appears to be substantially higher than some of the other treatments, but this was due to an abnormally high figure for this treatment in one of the replications only.

(ii) *White Clover:* Survival of white clover plants in the 15 lb. ryegrass sowing without barley was significantly higher (1 per cent level) than in all other treatments. For the remaining four treatments there were no significant differences.

Discussion

In Parts I and II of this series attention was paid to two criteria of considerable importance in pasture establishment: the provision of winter feed, and the early development of a balanced pasture, in which at the earliest possible stage, the nitrogen requirements of the grass are met by adequate clover growth. This paper is primarily concerned with the first criterion and with the possibility of taking advantage of the rapidity of growth of barley to provide winter feed. As with the previous experiments, the patterns of pasture development can be explained as the outcome of competition within and between species for light and, in the case of the grasses, for nitrogen.

The effects of seeding rate of ryegrass were similar to those reported in Part I, except for a few minor inconsistencies. The similarity is most apparent when responses to Treatments 1 and 2 are compared with those of identical treatments in the first experiment.

The percentage of viable ryegrass seeds which produced seedlings was higher at the light rate of seeding than at the heavy rate. This result differs from that shown in Part I but is similar to that obtained by Williams 1947). Also, total yields obtained over the full measurement period were much higher in this experiment than that reported in Part I. This difference is considered to be due in part to the different techniques used in the two experiments. In the first experiment each grazing was extended over 5 - 6 days, so that approximately 60 days of growth were not accounted for. In the present experiment the technique was such that all growth was accounted for in measurements of herbage yields.

These inconsistencies, however, did not affect the patterns of pasture development at the two seeding rates, nor do they effect the conclusions reached on the influence of ryegrass seeding rate on pasture establishment.

The inclusion of barley in the seed mixtures produced marked effects on the development and yield of individual species. In the early stages the fast growing barley depressed tiller development in the ryegrass. This effect was apparent first where ryegrass was sown at the heavier rate and later where the lighter seeding rate was used. Also, the mortality of clover seedlings was highest in plots where barley was sown. It is considered that these effects were mainly due to competition for light between barley and other sown species. The fact that ryegrass tiller development was depressed first at the heavier seeding rate, however, suggests that competition was not solely between barley and ryegrass, but was associated with intra-species competition between ryegrass tillers. Herbage yields obtained from ryegrass and clover in these mixtures during the first four months from sowing were consequently lower than in the no-cover-crop treatments. Over the same period barley produced approximately 900 lb. of dry matter per acre, and because of this, total yields obtained from the cover crop treatments were greater. This applied particularly to the barley comparison at the lighter ryegrass sowing rate, but at the high sowing rate the increase in total yield due to barley was smaller and was of little practical significance.

During the spring, barley yields were negligible, but the effect of the barley on growth and yield of other sown species was still apparent. Where barley had been sown there was a marked reduction in ryegrass yield but an increase in clover yield. The effect of this on total herbage production over the spring is shown as a reduction of approximately 10 per cent for the cover-crop treatments.

Yields obtained from ryegrass over this period were determined by the number and vigour of surviving clover plants and ryegrass tillers, and the supply of available soil nitrogen. It is considered that the supply of soil nitrogen was differentially lowered over the winter by leaching and the loss associated with the return of dung and urine to the sward by the grazing animal (Sears *et al.*, 1948: Doak, 1952). Consequently, the greatest losses would occur in the highest winter-yielding pastures where the turn-over of dung and urine was highest. The highest yielding treatments over the winter were those sown with barley. Also, clover survival was lowest in these treatments. It is significant, therefore, that the lowest yields of ryegrass were obtained from these treatments over the spring, and the highest yields from the treatments sown without barley, praticularly those where the ryegrass was sown at a light rate.

Clover yields during the spring were influenced (as in Part I) by the rapid development of buried clover seed. The highest yields were obtained from the cover crop treatments, but it was not until mid-spring, when ryegrass yields were affected by poor nitrogen nutrition and germination of buried seed occurred, that these increased yields were obtained.

During the summer and early autumn, ryegrass yields were limited by seasonal growth characteristics and differences obtained were not significant. Growth of clovers, on the other hand, increased markedly, and yields were determined by the vigour and number of plants in the pastures, at the commencement of summer. At this stage the cover crop

treatments were the highest yielding, but toward the end of summer the difference was reversed, and no significant differences in total clover yields were obtained.

The above discussion emphasises the point made in this and previous papers of this series that the production of high early yields of grass are associated with intense competition to the slower growing species. An unbalanced pasture results, and later yields are consequently lower. Where grass yields obtained over the winter are relatively low, as in the no-cover-crop treatments, a better balanced pasture is obtained, and the nitrogen requirements of the grass are met at an earlier stage. Later yields, and particularly yields obtained in the early spring, are then greater (cf. Fig. 1). It is concluded that the inclusion of barley in autumn sown pastures in areas similar to those in which this experiment was carried out, is not worthwhile, for the increase in winter herbage yield is small, and is offset by a greater reduction in spring yield.

Acknowledgement

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INJURY TO PHORMIUM CAUSED BY INSECTS, MITES, AND MOLLUSCS

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Summary

Various forms of injury to *Phormium* caused by insects, mites, and molluscs are described. Notes are given on biology of species concerned. A bibliography of *Phormium* entomology is appended.

Introduction

In June, 1949, the author commenced a study of insects associated with *Phormium,* the main object being to ascertain whether the "yellow-leaf" disease was connected with insect attack. A survey of species present gave little grounds for suspecting direct injury as the main causal factor, and attention was turned towards those insects which might be vectors of a pathogen. The cixiid, *Oliarus atkinsoni* Myers (Hemiptera: Homoptera), was incriminated as a vector of the disease in seedlings (Cumber, 1953a), but subsequent experimental work with this insect has not shown clearly whether a virus, fungal, or other pathogen is being transmitted (Cumber, 1953c).

During the initial survey and in subsequent experimental work, information on insects injuring *Phormium* has been gathered. A large number of species of varying importance are involved, and observations are for the most part fragmentary. Some of the injury described in the present account has been reported previously by such investigators as Atkinson (1922), Cockayne (1945), and Miller (1916, 1917 a, b, c, 1918, 1920, 1930) but additional damaging insects are recorded as such for the first time.

Insects

Odonata: Zygoptera

Lestidae: ***Austrolestes colensonis*** *Wh.* Puncture marks, often in transverse rows, have been observed on both fully grown *Phormium* in the field and on two-to-three-year-old seedlings in the nursery (Fig. 1). The insect responsible for these marks, which bear a strong resemblance to oviposition scars of homopterous insects, eluded detection until the paired female was observed ovipositing. Oviposition occurs at considerable distances from water, which is strange in view of the fact that larvae in the Odonata are aquatic. The injury caused is of a minor nature.

Thysanoptera

Two undentified species of thrips have been found feeding actively on *Phormium.* One is seldom numerous, in contrast to the other, which swarms over plants during some seasons at Paiaka.

For the greater part of the year nymphs and adults of this latter species are found within the closely folded younger blades, but populations reach their peaks in November and December on the flower-heads, where damage to flowers and bracts is noticeable.

Fig.1.—Oviposition scars caused by the zygopteron *Austrolestes colensonis.*
Fig. 2.—Injury to the mid-rib initiated by thrips.

A common feeding site is along the midrib where black marks remain as evidence (Fig. 2) once the blade has unfolded. The injury here is never extensive, but seed production may be impaired by flower-head attack.

Hemiptera: Homoptera

Cicadidae: ***Melampsalta cruentata*** *Fab.*: Considerable numbers of this insect are present in *Phormium* areas at Paiaka, and at an early stage in the investigation of the yellow-leaf condition were subject to experiment (Boyce *et al.* 1953). Nymphal populations of 20 to 30 per square foot commonly occur in drier plantations. There is some damage to roots as a result of nymphal feeding (Fig. 3), and oviposition scars (Fig. 4) are commonly found at the bases of blades. It is unlikely that severe injury is caused by this insect. The biology and ecology of the species has been studied in detail in the Paiaka area (Cumber, 1952a).

Cixiidae: ***Oliarus atkinsoni*** *Myers.* The biology and ecology of this species, which has been incriminated as a vector of the yellow-leaf disease has been studied at Paiaka (Cumber, 1952b, c, d).

Fig. 3.—Black dots mark the position of feeding punctures made by nymphs of the cicada, *Melampsalta cruentata.*

Fig. 4.—Oviposition scars of the cicada, *Melampsalta cruentata* on a leaf base.

In some areas very great numbers of nymphs swarm over roots within the old dead leaf-bases surrounding the rhizomes. It has been noted that considerable die-back in roots appears under this association. Nymphs puncture the roots with deep feeding traces which pass through the cortex to reach the central conducting elements. Secondary fungi are quick to exploit this injury. It seems possible that nymphs also transmit the yellow-leaf disease (Cumber, 1953c). This insect must be regarded as one of the more serious pests of *Phormium.*

Adults of the other New Zealand species *O. oppositus* Walk. occur commonly on *Phormium* in some areas, but large nymphal populations have not been found on this host plant.

Fulgoroidea: ***Scolypopa australis*** *(Walk.) (Ricaniidae) and* ***Sephena cinerea*** *Kirkaldy (Flatidae).* The latter species is occasionally taken on *Phormium* in the Paiaka area, but both species, and especially the former, which is commonly known as the "passion-vine hopper", occur in great number on *Phormium* in North Auckland districts. Although there is no apparent damage from *S. australis* in these areas, the great numbers present—sometimes hundreds to a single blade—must be a considerable drain on the sap stream.

Coccidae

Mealy-bugs. Although several species have been noted on *Phormium,* only one, *Trionymus diminutus* (Leonardi), is commonly

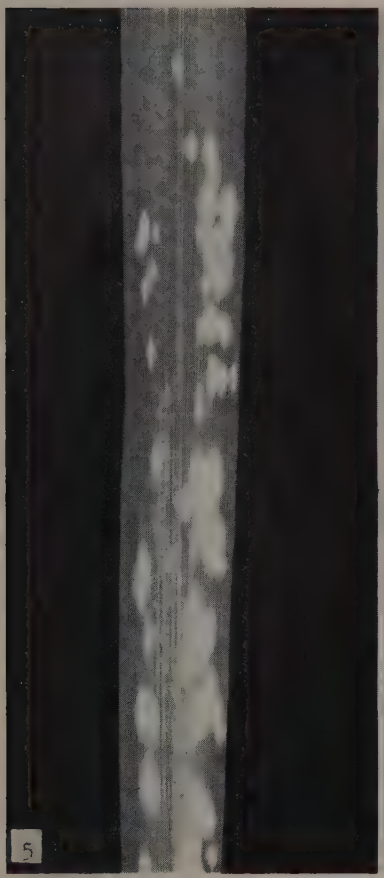

Fig. 5.—Chlorotic areas caused by the scale insect *Poliaspis media.*

Fig. 6.—A heavy infestation by *Poliaspis media* has caused considerable chlorosis. Clusters of scale material have been spun together by the tincid, *Batrachedra arenosella* (Walk). Sooty mould is also present.

present. Its favourite habitat is the sheathing leaf-bases where colonies are found in masses of mealy substance. Under dry conditions the bug may be found on roots and rhizome at, or slightly below, ground level. In aerial portions where leaf is in close apposition, small colonies are sometimes found.

A red discoloration is often present in tissues associated with colonies in leaf-bases. Under dry conditions there may be a considerable build-up of the bug—both in the field and in the glass-house. There appear to be several generations each year. An unidentified hymenopterous parasite is present.

Scale-insects. The most common species is the mussel-scale, *Poliaspis media* Mask. Numbers of a green circular scale *(Ctenochiton* sp.) are found occasionally. Both are hosts of hymenopterous parasites.

The mussel-scale often occurs in great numbers—usually on the lower surfaces of blades, and leaf-bases causing chlorotic spots several millimetres in diameter (Figs. 5, 6). Apart from this, there is no apparent detrimental effect. In small experimental seedlings where large populations have been introduced, general chlorosis of younger leaves has been observed. There are at least two generations each year. Crawlers have been observed hatching out in April and July. Black mould is often associated with coccid attacks on *Phormium*.

Aphididae: A moderate infection of young seedling material with *Aulacorthum solani* Kltb. has been observed in the glass-house at Paiaka. It was accompanied by chlorotic spotting. An unidentified aphid species occurs in small numbers on roots of *Phormium* in drier areas at Paiaka.

Lepidoptera

Flight records have been indicated for the Paiaka area (Cumber, 1951).

Hepialidae: ***Oxycanus (Porina) signata*** *(Walk.)*. Miller (1930) states that the crown and leaf-bases of the plant are attacked by the larvae of the hepialid moth *(O. signata)*, but that this insect had not become epidemic, and was not yet of major importance. He considered that apart from larval injury to the plant, the tissues were exposed to infestation by the spores of organisms causing rot to develop.

Damage to the rhizome has been noted (Fig. 7) but has not been detected on a serious scale. The species concerned has not been determined by rearing of incriminated larvae. Five species of *Oxycanus* were taken at light in *Phormium* areas at Paiaka. *O. Signata* is on the wing from January until March, with the flight peak in February.

Oxycanus caterpillars are very susceptible to changes in the level of ground water, and this restricts damage to areas where the water-table remains low.

Tineidae: ***Stathmopoda phlegyra*** *Meyr.* Hudson (1950) states that the larva of this insect feeds on the ripe seeds of New Zealand flax *(Phormium tenax)* in the autumn, joining the dried seeds together with silk inside the ripening pods, and feeding under cover. In this way it lives through the winter, the moths emerging in November. He indicates that there is probably more than one brood in the season as the perfect insect has been taken from October till January and in March and April.

Heavy infestations of this moth were observed at Paiaka. Moths were taken at light in small numbers during November and December. Heavy flowering of *Phormium* did not occur in the vicinity of the trap during its operation.

Tortricidae: ***Tortrix postvittana*** *Walk.* The caterpillars of this Australian moth attack a large number of plants in New Zealand spinning together leafy material to form the characteristic roll giving it the name "leaf-roller". It has not been recorded as a pest of *Phormium*, however, It attacks seedlings only, as mature leaf is too rigid to allow spinning together. In nurseries where plants are in their first and second years, damage is common but usually not on a serious scale. Leaves of adjacent plants where these touch, or leaves of the same plant are spun together for distances of up to four inches. Within this stronghold the developing

Fig. 7.—Caterpillar of the hepialid, *Oxycanus* sp. beside the hole which it had eaten in the rhizome.

Fig. 8.—Injury to young plant caused by caterpillars of the tortricid, *Tortrix postvittana*.

larva strips the surfaces of leaves, often causing a die-back of the more distal parts (Fig. 8). Sometimes the opposing surfaces of the one blade are spun together. The larvae pupate within spun material. Larval damage is most noticeable in March.

Flight records of the moths indicate that there are at least two, and possibly three, generations each year at Paiaka with adult emergence peaks in November, February, and May. Only during the months of August, December, and March were no moths taken.

Cnephasia jactatana *(Walk.).* Caterpillers of this moth feed upon *Phormium* seed which they retain within the opened pod by spinning it together. Late attempts at seed collection in the Paiaka area produce only damaged seed from spun clusters retained in pods.

Moths were taken at light from June till September and in February, the greatest number being recorded in June. It is doubtful if the species is restricted to *Phormium* heads in the Paiaka district.

Psychidae: ***Oeceticus omnivorus*** *Fereday.* This "bag-worm" moth has not been observed in great numbers on *Phormium.* Near Ka'kohe, North Auckland, bags of young caterpillars have been observed damaging tips and margins of leaf (Fig. 9). Miller (1930) states, "When the leaves of the latter (flax) are attacked the insect eats out large holes, and individual bushes have been found with many of the leaves severely damaged".

Fig. 9.—Bag of the psychid, *Oeceticus omnivorus* built of *Phormium* fragments.

Geometridae: ***Orthoclydon praefectata*** (Walk.). This insect may cause severe damage to *Phormium* plantations. Owing to serious outbreaks, investigations were carried out by Miller, (1916, 1917a, b, c, 1918, 1920, 1930) who has given a full account of the life-cycle and habits of this insect.

The damage caused by full-grown larvae is commonly termed "windowing" because of the thin layer of upper epidermis remaining after the underlying tissues have been eaten away (Fig. 10). The life-cycle has been determined through field observation and light trap records in the Paiaka area.

The moth lays groups of up to 90 eggs upon the backs of leaves. The caterpillars hatching out take shelter in rolled dead leaf to emerge and feed on green leaf at night. While caterpillars are small, they chew out long narrow strips one or two ridges wide, these being the first signs of an impending infestation. As they become larger, wider areas are chewed out until the typical damage at the height of an attack is seen. Pupation may take place within the rolled dead leaves or in the soil at the base of the plant.

Flight records indicate that there are two generations each year. Moths of the first (less numerous) generation appear from July till January, but mainly from November till January, with a peak in December. Damage by caterpillars of this generation, which is of a minor nature, is evident from January till March. Moths of the second (more numerous) generation appear in April and May, being present in approximately equal numbers during these two months. The caterpillars of this generation, which is the main damaging one, are present from June till September with the peak of active damage during August.

At the height of larval infestation, *Phormium* looks very ragged. The multiplicity of fibre-severing reduces the quality and yield of fibre very considerably. At this time, during daylight, the caterpillars may

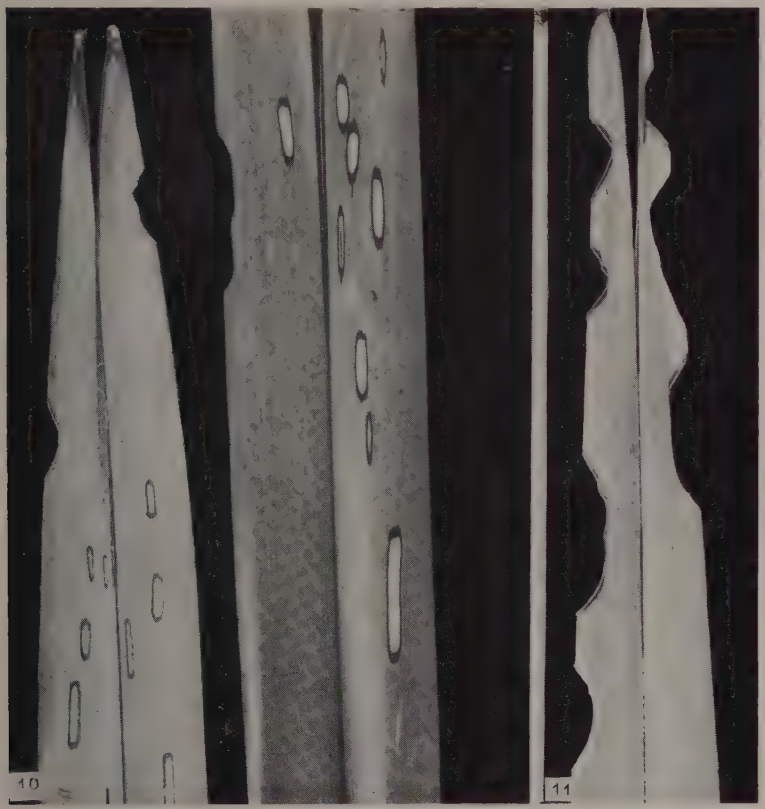

Fig. 10.—"Windowing" by the geometrid *Orthoclydon praefectata* as seen from the lower (L.) and upper (R.) surfaces of the blade.

Fig. 11.—"Notching" by the noctuid *Persectania steropastis*. The older damage is shown by the black edging of the notches.

be found in great numbers within the tightly rolled dead leaf present on bushes. Unthrifty plantations which produce greater amounts of prematurely dead rolled leaf foster depredations by this insect.

A series of experiments of a preliminary nature indicated that distinct preferences for certain varieties of *Phormium* are shown by caterpillars.

Noctuidae: ***Persectania steropastis*** *(Meyer.).* Injury by larvae of this insect has been called "notching" on account of the marginal "U" or "V" shaped pieces eaten from leaf in typical noctuid fashion (Fig. 11). The life-cycle has been studied by Miller (1930). Field observations and light trap records from the Paiaka area provide further information.

The moths are present during every month of the year but are most plentiful in September, and March-April. Newly damaged leaf has been

observed during every month except November, and seems to be most prevalent in January and February, and from May till July. There appear to be two extended generations each year.

The moths deposit eggs on the leaf of *Phormium* bushes. Larvae hatching out seek shelter in rolled leaf during daylight. Pupation may take place within dead leaf sheaths or in the dry soil about the base of the plant.

No infestations causing damage on the scale seen in the case of "windowing" by *O. praefectata* have been observed, but the insect must be regarded as important. Miller (1930) states that "it is more abundant upon the hill-flax of Southland than elsewhere".

Coleoptera

Scarabacidae: ***Costelytra (Odontria) zealandica*** *(White).* Small populations feeding upon finer roots are present in drier areas. They have not been observed in sufficient numbers to be regarded as important.

Curculionidae: ***Catoptes*** *sp.* Considerable larval populations of this native weevil cause marked damage to roots. In drier parts at Paiaka there is scarcely an undamaged root to be found except at deeper levels. The larvae tunnel along the sides of larger roots (Fig. 12) burrowing deep into the cortex. Although the central conducting elements are seldom chewed, the widespread cortical damage allows the entrance of secondary organisms and root death follows.

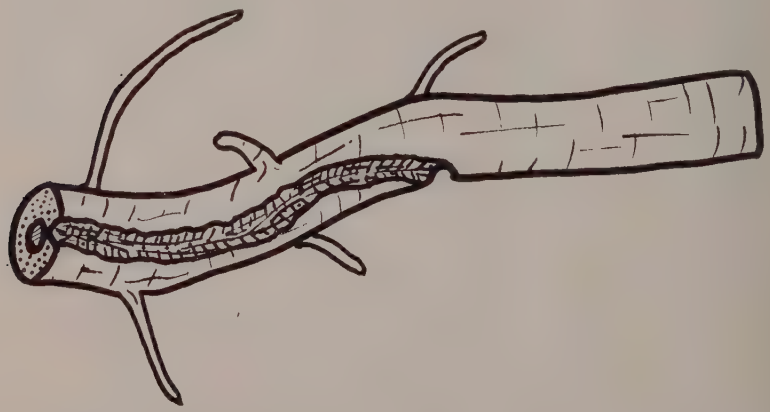

Fig. 12.—Channeling of main root by larva of the weevil, *Catoptes* sp.

Adults have been observed from December till March, and in August, and pupae from November till March. Larval stages are present from April till November. It seems probable that a few adults overwinter as such.

Gourlay (1931) records attacks on *Phormium* leaf by a weevil *Phaeophanus fairburni* Brookes on D'Urville Island.

Diptera

Miller (1930) refers to a chloropid from seed-pods, and a hover-fly and chironomid from gum fluid which gathers between the bases of the older blades. None of these is responsible for noticeable injury.

Cecidomyidae

Damage caused by pink cecidomyid larvae has been observed at Paiaka in seed-pod and on leaf. The former could be important in seed collection, and the latter does cause loss of leaf. Adult flies have been observed on pods in the field, and have been reared from larval material, but attempts to rear adults from leaf-base larvae have been unsuccessful.

On seed-pod

In November and December when petals have fallen and seed-pods are approaching full size, adults of the cecidomyid are observed pushing eggs, by means of their long tubular ovipositors, into the pods along the lines separating seed chambers. Often working simultaneously with the cecidomyid, a platygasterine parasite, similarly equipped as regards ovipositor, deposits its eggs, presumably within those of the host. Egg masses and larvae have also been observed within unopened flowers. Adults hatched out in January from infested seed-pods placed on sand during December.

On leaf

The larvae attack the base of the youngest leaf in the fan where it is protected by the enclosing outer leaf bases. As many as 50 have been observed living in a slime surrounding the young leaf.

Injury in its earliest stages is evident as chlorosis and grooving as the growing leaf advances past the seat of the damage. Grooves are often reddish before they emerge above the sheathing leafbases, but once they are exposed to the air they blacken and secondary organisms appear to assist in extending the damage (Figs. 13, 14, 15). Eventually the expanded blade contains jagged, elongated holes with marginal blackening, or if the attack is severe, the youngest blade may collapse and fungal attack spread to new blades attempting to come through. It is possible that this type of injury, which has not been recorded previously, has been regarded as frost damage.

Larvae are present from March till August and in November, but further information is required before the life-cycle is understood. It is possible that seed-pod and leaf injury is caused by the one species.

Mites

Tetranychidae: ***Septanychus*** sp. Considerable injury to *Phormium* seedlings has been caused under glass-house conditions (Fig. 16) by this mite. The mites may build up to such numbers that together with their webbing, they form balls half an inch in diameter on tips of leaves. A marked chlorosis accompanies the attack. Injury to *Phormium* bushes by the same species has been observed in the vicinity of Paekakariki.

Figs. 13, 14, 15.—Injury by the cecidomyid larvae found at leaf bases. The early stage (Fig. 13) may be followed by collapse of the leaf (Fig. 14) or jagged holes in the expanded blade (Fig. 15).

Fig. 16.—Chlorosis in seedlings caused by the tetranychid mite *Septanychus* sp.

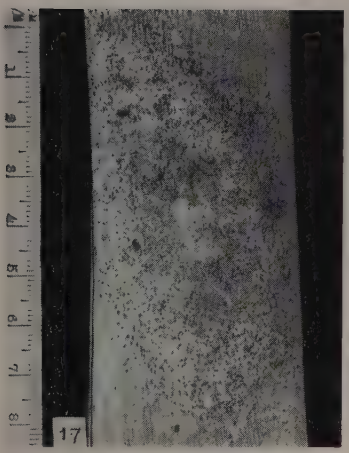

Fig 17.—A colony of the tetranychid mite *Septanychus* sp. on the full grown blade. Note the beetles, *Iphidulus* sp. feeding on eggs.

Fig. 18.—"V"-shaped markings caused by the eriophyid mite, near *Rhyncaphytoptus* sp.

Septanychus sp. This species was first noted by Dr. F. J. Newhook at Paiaka where it occurs commonly. A report from Dr. G. W. Baker, U.S. Department of Agriculture states that: "The *Septanychus* sp., or *Tetranychus* of European workers is closely related to *Tetranychus bimaculatus* Harvey. This mite is not known in this country nor does it appear to be European or Australian". Although it is common at Paiaka, the attendant damage is not serious. A beetle, *Iphidulus* sp. (Laelaptidae) is commonly found in association with colonies, feeding upon eggs (Fig. 17). The colonies cause chlorosis, and reddening in some cases.

Eriophydiae: Near ***Rhyncaphytoptus*** sp. A species of gall mite occurring commonly on *Phormium* at Paiaka is responsible for reddening which often assumes "V"-shaped patterns on the upper surface of leaves (Fig. 18).

In the younger stages the upper surfaces of the two sides of the blade are in close apposition. Between the surfaces a gummy fluid is present, the amount varying with weather conditions. As the leaf

Fig. 19.—Injury in seedlings caused by the common garden snail, *Helix aspersa*.

Fig. 20.—Injury in seedlings caused by introduced slugs.

opens out the level of the liquid takes an oblique line. The varying levels and concentrations of dried deposit could both contribute to the variation in feeding damage which gives the ultimate pattern. Little damage is caused by this species.

Tyroglyphidae: ***Rhysoglyphus echinopus*** *(Fum. et. Robin).* This bulb mite is commonly present on the rhizome of both seedling and full-grown bushes at Paiaka, but is probably a secondary invader.

MOLLUSCS

Helicidae: ***Helix aspersa*** *Mull.* In the *Phormium* areas at Paiaka great numbers of this common garden snail are present in both plantation and swamp. During certain seasons they climb up blades and rest in conspicuous clusters. Little damage is apparent on *Phormium* bushes, the snails subsisting on surrounding vegetation. In nurseries, however, damage to young plants (Fig. 19) has been observed in November.

Introduced Slugs

Severe damage (Fig. 20) has been observed in nurseries in November.

Athoracophoridae: ***Athoracophorus bitentaculatus*** *(Quoy et Gaimard).* This native slug is common on *Phormium* in most areas. Damage is restricted to the removal of bloom from the lower surface of blades and leaf-bases. There is no noticeable secondary attack.

DISCUSSION

In evaluating the importance of the different species known to injure *Phormium,* direct and indirect injury both have to be considered. The admission of secondary pathogenic organisms is possibly more important than mechanical injury.

In addition, the method of cultivation will govern the populations of the different species. Freedom from insect damage and the vigor which attends *Phormium* receiving periodical natural flooding, are in marked contrast to these conditions in established plantations on the younger, sandy, high-level areas immediately adjacent to the river. Not only is it probable that expense involved in the laying out of plantations for controlled flooding will be well repaid, but maintenance of plantations may prove possible only under such conditions.

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CALYX-END BREAKDOWN: AN UNUSUAL FORM OF BREAKDOWN IN STURMER PIPPIN APPLES

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Summary

A physiological breakdown of Sturmer apples is described.

It is suggested that a suitable name would be calyx-end breakdown, to distinguish it from brown heart, crinkle and true internal breakdown.

No means of controlling the disorder are known.

Introduction

A form of flesh breakdown in cool store was the cause of serious losses in Sturmer Pippin apples in the Hastings district during 1953. Losses of up to 29 per cent were recorded. A previous outbreak occurred in fruit from the same district in 1947, while McClelland and Tiller (1926) briefly mentioned and illustrated fruit similarly affected. As this form of breakdown appears to differ in various respects from forms already described the name calyx-end breakdown is proposed.

Symptoms

At harvest the fruits appears normal. Internal symptoms develop by mid-June when fruit is still hard and green. When cut transversely near the calyx, affected apples show a dark chocolate brown discolouration, the edges of which are sharply outlined. Massive, irregular shaped patches of affected tissue are located in an uneven or broken ring outside the core-line (Fig. 1). There is usually a band of healthy tissue between the core-line and the inner edge of discoloured tissue. In many fruits, numerous cavities form in affected tissue, giving it a spongy texture. Symptoms are usually confined to the calyx end (Fig. 2), but occasional fruits may have the entire flesh affected.

The disorder is not visible externally while the skin is green, but when this changes to yellow, a dark discolouration or shadow can be seen through the skin.

Examination of commercial lines has shown that the appearance of this disorder is very sudden and extensive areas suggest that if apples do not become affected by mid-July, they remain sound.

Calyx-end breakdown may occur on fruit left on the tree to ripen and it can develop in fruit in both non-refrigerated and refrigerated storage. Where fruit is cool stored, there is some evidence that lower temperatures reduce development of the disorder.

In general symptoms, this disorder is not unlike "brown heart" which is caused by accumulation of excessive concentrations of carbon dioxide. Although no measurements of carbon dioxide concentration in chamber atmospheres were made during 1953, it is considered very unlikely that sufficient accumulation of this gas could have occurred to induce brown heart.

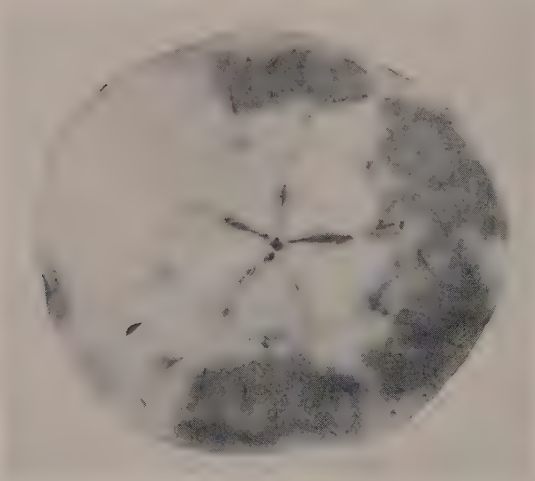

Fig. 1. Transverse section of Sturmer apple showing calyx-end breakdown before cavities have developed.

Photo: J. W. Endt

Fig. 2. Longitudinal sections of Sturmer apples showing cavities associated with calyx-end breakdown.

Photo: J. W. Endt

Calyx-end breakdown has been known among cool store operators as crinkle or crinkle breakdown. Its appearance is similar to crinkle as described by Atkinson (1947); however, calyx-end breakdown differs from crinkle in that apples do not show external distortion round the calyx (Fig. 2), nor does fruit on the tree show symptoms at normal picking time.

Confusion with internal breakdown is possible but there are distinctions between the two disorders. Calyx-end breakdown takes on a definite outline, and all tissue within the boundaries of a lesion is dead and shows an almost uniform intensity of relatively dark brown colour. Lesions of internal breakdown have diffuse edges and their colour is seldom uniform. Internal breakdown is often found only at the stalk end of apples.

INCIDENCE

Calyx-end breakdown has been observed sporadically since 1925 in Sturmer apples grown in both Hawkes Bay and Nelson. The only severe outbreaks have been in 1947 and 1953, both of which were confined to Hawkes Bay fruit. Out of 132 orchards where Sturmers are grown, fruit from 22 orchards in 1947 and 34 orchards in 1953 was affected. Only two orchards producing affected fruit in 1947 also produced it in 1953.

SURVEY OF AFFECTED ORCHARDS IN 1953

A survey of orchards which had produced affected fruit failed to reveal any common factor that might have caused calyx-end breakdown. Both 1947 and 1953 were years of light crop following years of exceptionally heavy crop, but this phenomenon was common to the whole Hastings area and not confined to particular orchards. Affected fruit was produced from orchards situated on all the principal soil types of Hawkes Bay. Pruning methods, manurial programmes, and tree vigour appeared to have no effect on the incidence of this disorder. Fruit that had been withheld from storage for a short period after harvesting appeared to be as susceptible as fruit delivered to cool store immediately after picking.

The disorder was more severe in the later picked fruit from all affected orchards.

CLIMATIC CONDITIONS

McClelland and Tiller (1926) reported that this form of breakdown appeared to be connected with heavy rains following dry weather, and also with increasing maturity of the fruit. These weather conditions were experienced during the summer of 1948-47 in Hastings. The summer of 1952-53 by comparison was extremely wet, and it seems unlikely that heavy rain following a drought is the primary cause of calyx-end breakdown.

CONTROL

There are no known means of controlling calyx-end breakdown. Lines of fruit in which it occurs must be held until the skin colour turns from green to yellow, when affected fruits can be detected. These can then be rejected, while the remainder are repacked for market. Lowering storage temperature is not recommended as a method of control, as this would almost certainly cause serious loss from internal breakdown.

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CONTROL OF BLACK SPOT OF APPLES

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Summary

Three season's experiments in control of black spot of apples are described. Fungicides containing ferbam or thiram applied over the whole season gave control equal to that obtained with "standard" programmes of Bordeaux mixture and sulphur. On Delicious, Dougherty, Dunn's Favourite, Granny Smith, Jonathan and Parlin's Beauty, applications of phenyl mercury chloride did not cause excessive damage and gave control of black spot equal to standard programmes, but with Sturmer in Hastings (though not in Auckland), Cox's Orange and Crimson Cox, damage to trees was severe. Phenyl mercury triethanol ammonium lactate and captan were not widely tested but showed promise. Four other fungicides, wettable sulphur, colloidal copper, a glyoxalidine complex and dichloro naphthoquinone, were unsatisfactory.

Owing to possible occurrence of mercury residues on fruit, phenyl mercury chloride should be replaced after mid-December applications by less toxic fungicides.

Introduction

Black spot, caused by *Venturia inaequalis* (Cke.) Alderhold, is one of the major fungous diseases of apples in New Zealand. Until recently, spraying programmes to control black spot have included Bordeaux mixture, lime sulphur or colloidal sulphur, or combinations of these materials (Anon., 1946). Over the last few years, however, with the introduction of newer organic fungicides, attempts have been made to devise programmes that would give effective control without russet. The present paper describes experiments with several materials during the seasons 1950/51, 1951/52 and 1952/53.

Materials And Methods

Trials were conducted in three districts and on several varieties as follows:

Auckland: Granny Smith, Jonathan, Sturmer, Parlin's Beauty.
Hastings: Crimson Cox, Sturmer, Dougherty.
Nelson: Cox's Orange, Dunn's Favourite, Delicious.

Experiments were laid out in blocks of 1- or 2-tree replicates, and sprays were applied from the ground with lances.

In the text the strength of fungicide used is given as the amount required for 100 gal. of spray. All fungicides used are included in the following list:—

Bordeaux mixture x/y/100	—x lb. copper sulphate/y lb. hydrated lime (95% calcium hydroxide) in 100 gal.
Ascospray	—2.5% phenyl mercury chloride; wettable powder.
Venturicide	—2.5% phenyl mercury chloride; wettable powder.
Mercurated lead arsenate	—2 parts phenyl mercury chloride with 98 parts lead arsenate; wettable powder.

Puratized	—5% phenyl mercury triethanolammonium lactate; liquid.
Colsul 25	—25% colloidal sulphur; paste.
Colsul 40	—40% colloidal sulphur; paste.
Cosan	—80% sulphur; wettable powder.
Lime sulphur	—15% polysulphide; liquid.
Fungex	—8.5% copper; liquid.
Ialine Copper	—15% colloidal copper; emulsion.
Crag 341C	—34% mixed glyoxalidines; liquid.
Fermspray	—70% ferbam; wettable powder.
Flit-406	—50% captan; wettable powder.
Phygon XL	—50% dichloro naphthoquinone; wettable powder.
Thirospray	—50% thiram; wettable powder.

In general, fruit records were taken from a random sample of one loose bushel case per tree. However, from Sturmer, Parlin's Beauty and Dougherty in Auckland which were dwarf trees, the whole crop was examined. Records of leaf infection were made by sorting 100 leaves from each tree picked at random, as infected or clean without grading degree of infection on single leaves. To measure spray damage to leaves, 100 from each tree were graded as "clean", "slight" (1-10 % of leaf area damaged), "moderate" (10-25 %), "heavy" (25-50 %), or "excess" (over 50 % of leaf area damaged).

In the experiments a "standard programme" against which others may be compared was included. This standard programme varies among districts and differs between varieties ,and for that reason is not identical throughout experiments cited. However, it invariably includes one or more of only three fungicides, Bordeaux mixture, lime sulphur, and colloidal sulphur, and can readily be recognised in the tables.

RESULTS

Tables 1-7 set out programmes, together with details of infection and spray damage. An experiment on Granny Smith at Auckland in the 1952/53 season has not been included, but two materials used in it caused plant damage. Phygon XL, 1 lb. at petal-fall and 0.5 lb. in five later applications, caused severe fruit russet. Fungex, 4 pt. at green tip, 3 pt. at pink and petal-fall, and 2 pt. in five later applications, severely damaged leaves and caused heavy rough russet on all fruit. No black spot developed on Cox's Orange in Nelson in experiments laid down in 1951-52. The use of Ascospray on this variety caused heavy foliage injury followed by leaf-drop, and by February, under all treatments (Table 2) except (d) and (e), trees had become severely defoliated. On Dunn's Favourite (Table 2), spray injury was confined to leaf spotting, and there was no defoliation.

DISCUSSION

In most cases programmes including organic fungicides gave approximately the same control of black spot as standard programmes. It appears from Table 2 that the period about petal-fall and closed calyx is critical in control of fruit infection. In the only experiment where it occurred, omission of green tip applications did not affect the amount of black spot on fruit (Table 6).

The fungicides used may be considered individually. At the concentrations used, five were unsatisfactory. Cosan failed to control black spot (Table 5), while Ialine Copper (Table 5) and Fungex damaged trees, and Crag 341C (Table 6) and Phygon XL caused excessive fruit russet.

In the limited use made of it, Flit-406 controlled fruit infection (Table 6). Fermspray used during flowering or until mid-December, followed by Thirospray, Colsul 40 or a mixture of Fermspray and Colsul 40, gave fair control of fruit infection without causing excess russet (Tables 4, 6, 7). Where Fermspray was replaced by Thirospray in the programmes outlined, similar results were obtained (Tables 6 and 7).

Puratized used during flowering and until the end of November, followed by sulphur and Bordeaux mixture, performed as well as the other organic mercury sprays and caused no more fruit russet than a standard programme (Table 7). Used throughout the season, Puratized gave control equal to that with phenyl mercury chloride sprays (Table 1).

Of the phenyl mercury chloride sprays, Mercurated lead arsenate was, at the concentrations used, less effective than Ascospray and Venturicide (Table 1), but it must be allowed that there was less phenyl mercury chloride applied in the Mercurated lead arsenate sprays than in the other two. Applied throughout the season, Ascospray and Venturicide gave similar control of infection (Table 1). However, spraying with these materials later than mid-December has been found to leave a residue of mercury on fruit greater than the amount considered safe for human consumption. When they were used not later than mid-December and were followed by other materials, control was still satisfactory (Tables 3, 4, 5, 7). Table 2 shows that Ascospray gave better control of fruit infection than Colsul 25. Offsetting the control of black spot obtained with Ascospray and Venturicide was the frequent occurrence of damage to trees. Severe damage was suffered by the varieties Cox's Orange, Crimson Cox and Sturmer (Tables 3, 7). Some leaf damage sometimes occurred on other varieties, though on these fruit russetting was no greater than on trees sprayed with standard programmes, and fruit colour was not affected.

Conclusion

From the exeriments cited it is evident that control of black spot as good as that obtained with standard programmes of Bordeaux mixture and sulphur is given by the following:

Until closed calyx, thiram at 0.15 % or ferbam at 0.21 % may be used. For the rest of the season thiram at 0.1 % or ferbam at 0.14 % is suitable. On varieties known to be resistant to damage, phenyl mercury chloride at 0.005% may be applied until mid-December.

Phenyl mercury triethanolammonium lactate and captan, while showing promise, have not been tested sufficiently to allow an assessment of their relative efficiency.

Acknowledgments

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TABLE 1. USE OF ORGANIC MERCURY SPRAYS AGAINST BLACK SPOT ON GRANNY SMITH APPLES, AUCKLAND, 1951/52 (4 Single-tree Plots per Treatment)

Application Time	Treatments									
	a	b	c	d	e	f	g	h	i	j
Open cluster pink 2/10/51	No spray	Lime sulphur 0.7 gal.	Puratized 15 fl. oz.	Puratized 30 fl. oz.	Ascospray 1 lb.	Ascospray 2 lb.	Venturicide 1 lb.	Venturicide 2 lb.	Mercurated lead arsenate 1 lb.	Mercurated lead arsenate 2 lb.
Petal-fall, 24/10/51 and again 8/11/51	,,	Lime sulphur 0.5 gal. + Colsul 40 2 lb.	,,	,,	,,	,,	,,	,,	,,	,,
27/11/51	,,	,,	Puratized 7.5 fl. oz.	Puratized 15 fl. oz.	Ascospray 0.5 lb.	Ascospray 1 lb.	Venturicide 0.5 lb.	Venturicide 1 lb.	Mercurated lead arsenate 0.5 lb.	Mercurated lead arsenate 1 lb.
2/1/52	,,	Bordeaux 2/6/100	,,	,,	,,	,,	,,	,,	,,	,,
23/1/52 and 25/2/52	,,	,,	Puratized 4 fl. oz.	Puratized 7.5 fl. oz.	Ascospray 0.25 lb.	Ascospray 0.5 lb.	Venturicide 0.25 lb.	Venturicide 0.5 lb.	Mercurated lead arsenate 0.25 lb.	Mercurated lead arsenate 0.5 lb.
% fruit infection	92.2	1.1	14.7	6.0	13.4	2.7	13.4	4.7	22.0	16.3
Mean equivalent angle:	73.77	6.08	22.56	14.21	21.50	9.50	21.47	12.49	27.95	23.80
Differences for significance at: 5% = 9.5 1% = 12.7										

NOTES:—Applications at green tip were omitted on all treatments. The following insecticides were applied to all treatments: 8 sprays of lead arsenate, 1.5 lb., plus hydrated lime, 3 lb., and 2 applications of 1 per cent. summer oil. A small amount of fruit russetting occurred under treatment (b); all other fruit was free of russet.

TABLE 2. SUBSTITUTION OF PHENYL MERCURY CHLORIDE FOR COLLOIDAL SULPHUR AGAINST BLACK SPOT ON DUNN'S FAVOURITE APPLES, NELSON, 1951/52 (4 Single-tree Plots per Treatment)

Application Time	Treatments							
	a	b	c	d	e	f	g	h
Green tip, 18/9/51	Ascospray 2 lb.	Ascospray 2 lb.	Ascospray 2 lb.	Ascospray 2 lb.	Colsul 25 6 lb.	Colsul 25 6 lb.	Colsul 25 6 lb.	Colsul 25 6 lb.
Open cluster—pink, 1/10/51	,,	,,	,,	,,	,,	,,	,,	Ascospray 2 lb.
Petal-fall, 15/10/51	,,	,,	,,	Colsul 25 6 lb.	,,	,,	Ascospray 2 lb.	,,
Closed calyx, 6-7/11/51	,,	,,	,,	,,	,,	Ascospray 2 lb.	,,	,,
22/11/51	,,	,,	Colsul 25 6 lb.	,,	,,	,,	,,	,,
13/12/51	,,	,,	,,	,,	,,	Colsul 25 6 lb.	,,	,,
12/1/52	,,	Colsul 25 6 lb.	,,	,,	,,	,,	Colsul 25 6 lb.	,,
5/2/52	,,	,,	,,	,,	,,	,,	,,	Colsul 25 6 lb.
% fruit infection	0.7	2.8	8.4	21.8	28.3	18.2	4.8	5.4
Mean equivalent angle	4.87	9.59	16.89	27.85	32.12	25.26	12.65	13.40
Differences for significance at: 5% = 8.6 1% = 11.7								
% leaf infection	1.6	1.0	24.9	28.6	32.8	30.6	10.3	11.9
Mean equivalent angle	7.33	5.77	29.95	32.31	34.92	33.61	18.70	20.22
Differences for significance at: 5% = 9.6 1% = 13.1								
Leaf damage index*	0.89	0.75	0.45	0.26	0.25	1.01	0.76	0.69
Differences for significance at: 5% = 0.26 1% = 0.35								

*Leaf damage index: $X = \frac{pq}{n}$ where q = O (clean); 1 (slight); 2 (moderate); 3 (heavy); 4 (excess).
p = number leaves in each grade.
n = total leaf number.

NOTE:—The following insecticides were applied to all treatments: Winter oil, 5% at dormant: DDT, ¼ lb. p.p.i. in 5 applications after petal-fall; and summer oil, 1% in 2 applications.

TABLE 3. COMPARISON OF PHENYL MERCURY CHLORIDE WITH A LIME SULPHUR/SULPHUR PROGRAMME USED UNTIL CLOSED CALYX AGAINST BLACK SPOT ON COX'S ORANGE, DELICIOUS AND DUNN'S FAVOURITE APPLES, NELSON, 1952/53

(8 Single-tree Plots of Each Variety Per Treatment)

Application Time	Treatments		
	a	b	c
Green tip, 16/9/52	Lime sulphur 3.3 gal.	Ascospray 2 lb.	Venturicide 2 lb.
Open cluster—pink, 29/9/52	Lime sulphur 0.7 gal. +Colsul 25, 2 lb.	,,	,,
Petal-fall, 16/10/52 and closed calyx, 28/10/52	Colsul 25, 6 lb.*	,,	,,
21/11/52, 12/12/52 and 7/1/53	Thirospray 2 lb.	Thirospray 2 lb.	Thirospray 2 lb.
Cox's Orange			
Percentage fruit infection	4.4	3.1	2.1
Mean equivalent angle	12.1	10.1	8.3
Differences for significance at:			
5% = 2.6			
1% = 3.6			
Delicious			
Percentage fruit infection	3.5	4.2	2.9
Mean equivalent angle	10.78	11.84	9.80
Differences for significance at:			
5% = 4.44			
1% = 6.16			
Dunn's Favourite			
Percentage fruit infection	3.5	1.4	0.3
Mean equivalent angle	10.83	6.91	2.98
Differences for significance at:			
5% = 4.14			
1% = 5.75			

*On Delicious, lime sulphur, 0.5 gal., and Colsul 25, 4 lb., were used instead of Colsul 25, 6 lb., at both petal-fall and closed calyx applications.

NOTES:—The following insecticides were applied to all treatments: Winter oil, 5% at dormant; DDT, $\frac{1}{4}$ lb. p.p.i. in 5 applications after petal-fall and 2 applications of 1% summer oil in January.

On Dunn's Favourite spray burns appeared on leaves after the closed calyx application of Treatments (b) and (c), Treatment (c) being the more severe, and some leaf-drop occurred.

By 15th December leaf-drop had ceased.

On Delicious there was no spray damage to leaves. Fruit was of high colour with all treatments, and there was little russet.

On Cox's Orange leaves became burnt, and defoliation began after the petal-fall applications of Treatments (b) and (c). This leaf-drop continued steadily until early December before ceasing. Treatment (a) caused no leaf damage. No treatment caused a significant amount of fruit russet.

TABLE 4. COMPARISON OF ORGANIC FUNGICIDES WITH A STANDARD PROGRAMME AGAINST BLACK SPOT ON STURMER APPLES, AUCKLAND, 1950/51 (5 Two-tree Plots per Treatment)

Application Time	Treatments			
	a	b	c	d
Green tip, 21/10/50	Bordeaux 10/8/100	Bordeaux 10/8/100	Bordeaux 10/8/100	No Spray
Opencluster—pink, 3/11/50	Lime sulphur 0.7 gal.	Venturicide 2 lb.	Fermspray 3 lb.	„ „
Petal-fall, 14/11/50	Lime sulphur 0.5 gal. + Colsul 40 1 lb.	Venturicide 1.5 lb. + Colsul 40 1 lb.	Fermspray 3 lb. + Colsul 40 1 lb.	„ „
29/11/50 and 19/12/50	„	Venturicide 1.5 lb.	Fermspray 2 lb.	„ „
10/1/51 and 4/2/51	Bordeaux 2/6/100	Bordeaux 3/6/100	Thirospray 2 lb.	„ „
26/2/51	Lime sulphur 0.5 gal. + Colsul 40 1 lb.	Bordeaux 2/6/100	„	„ „
% fruit infection	8.1	2.1	2.6	21.3
Mean equivalent angle	16.5	8.3	9.2	27.5
Differences for significance at: 5% = 10.0 1% = 13.9				
% Fancy fruit (russet grading)*	31.8	35.4	35.7	36.1
Mean equivalent angle	34.3	36.5	36.7	36.9
Differences for significance at: 5% = 10.4 1% = 14.5				

*Russet grading: "Fancy" has maximum allowance of 60% russet.

NOTE:—The following insecticides were applied to all treatments: Winter oil, 5% at dormant; DDT ¼ lb. p.p.i. at petal-fall and in January; 3 applications of lead arsenate 1.5 lb. and hydrated lime 3 lb. following the first DDT and one application following the second DDT; 2 applications of 1% summer oil in January.

TABLE 5. COMPARISON OF SEVERAL FUNGICIDES USED AGAINST BLACK SPOT ON PARLIN'S BEAUTY APPLES AUCKLAND, 1952/53 (3 Single-tree Plots Per Treatment)

Application Time	Treatments						
	a	b	c	d	e	f	g
Open cluster pink, 29/9/52	No Spray	Lime sulphur 0.5 gal.	Colsul 40 4 lb.	Lime sulphur 0.5 gal. + Colsul 40 2 lb.	Cosan 1.5 lb.	Ialine Copper 5 lb.	Ascospray 2 lb.
Petal-fall, 21/10/52	,,	Lime sulphur 1.3 gal.	Colsul 40 6 lb.	Lime sulphur 1.3 gal.	Cosan 3 lb.	Ialine Copper 20 lb.	,,
Closed calyx, 5/11/52	,,	Lime sulphur 0.7 gal.	,,	Lime sulphur 0.7 gal + Colsul 40 2 lb.	,,	Ialine Copper 10 lb.	,,
26/11/52, 9/12/52, 30/12/52, 22/1/53 and 12/2/53	,,	,,	,,	,,	,,	,,	Thiospray 2 lb.
% fruit infection	69.1	35.2	50.6	24.6	65.7	2.0	2.1
Mean equivalent angle	56.22	36.41	45.32	29.71	54.17	8.04	8.25
Differences for significance at: 5% = 25.02 1% = 33.82							

NOTES:—The green tip application has been omitted in this trial.

The following insecticides were applied to all treatments: 6 applications of 1.5 lb. lead arsenate and 3 lb. hydrated lime were made through the season.

Treatment (f) caused severe leaf damage after both the Open cluster—pink and Petal-fall applications, and some further leaf damage with subsequent applications.

TABLE 6. COMPARISON OF SEVERAL FUNGICIDES AGAINST BLACK SPOT, WITH OMISSION OF GREEN TIP APPLICATIONS FROM SOME PROGRAMMES, ON JONATHAN APPLES, AUCKLAND, 1951/52
(4 Single-tree Plots per Treatment)

Application Time	Treatments													
	a	b	c	d	e	f	g	h	i	j	k	l	m	n
Green tip, 17/9/51	No spray	Bordeaux 10/8/100	No spray	No spray	No spray	No spray	No spray	No spray	Asco-spray 2 lb.	Ventur-icide 2 lb.	Ferm-spray 3 lb.	Thiro-spray 3 lb.	Flit-406 3 lb.	Crag 341C 2 pt.
Pink, 26/9/51	„	Lime sulphur, 0.7 gal.	Asco-spray 1 lb.	Ventur-icide 1 lb.	Ferm-spray 2 lb.	Thiro-spray 2 lb.	Flit-406 2 lb.	Crag 341C 1 pt.	Asco-spray 1 lb.	Ventur-icide 1 lb.	Ferm-spray 2 lb.	Thiro-spray 2 lb.	Flit-406 2 lb.	Crag 341C 1 pt.
Petal-fall, 24/10/51 and again 8/11/51	„	Lime sulphur 0.5 gal. + colsul 40, 2 lb.	„	„	„	„	„	„	„	„	„	„	„	„
26/11/51	„	„	Asco-spray 0.5 lb. + Col-sul 40 2 lb.	Ventur-icide 0.5 lb. + Col-sul 40 2 lb.	Ferm-spray 1 lb. + Col-sul 40 2 lb.	Thiro-spray 1 lb. + Col-sul 40 2 lb.	Flit-406 1 lb.	Crag 341C 0.5 pt.	Asco-spray 0.5 lb. + Col-sul 40 2 lb.	Ventur-icide 0.5 lb. + Col-sul 40 2 lb.	Ferm-spray 1 lb. + Col-sul 40 2 lb.	Thiro-spray 1 lb. + Col-sul 40 2 lb.	Flit-406 1 lb.	Crag 341C 0.5 pt.
3/1/52	„	Bordeaux 2/6/100	„	„	„	„	„	„	„	„	„	„	„	„
28/1/52 and 20/2/52	„	„	Asco-spray 0.25 lb. + Col-sul 40 2 lb.	Ventur-icide 0.25 lb. + Col-sul 40 2 lb.	„	„	„	„	Asco-spray 0.25 lb. + Col-sul 40 2 lb.	Ventur-icide 0.25 lb. + Col-sul 40 2 lb.	„	„	„	„

% friut infection	21.6	0.0	1.1	0.0	0.8	0.1	0.2	0.5	1.6	1.6	1.1	0.2	0.2	0.1
Mean equivalent angle	27.67	0.0	6.05	0.0	5.06	1.20	2.56	3.91	7.18	7.31	5.98	2.72	2.80	1.20
Differences for significance at: 5% = 6.58 1% = 8.83														
%Fancy fruit (russet grading)*	49.6	29.0	48.8	48.0	42.9	38.3	40.7	19.7	56.4	43.6	33.7	34.0	41.6	25.2
Mean equivalent angle	44.76	32.59	44.30	44.33	40.94	38.22	39.64	26.36	48.69	41.32	35.50	35.65	40.16	30.10
Differences for significance at: 5% = 5.23 1% = 7.68														
% Fancy fruit (colour grading)*	77.8	78.3	70.0	73.8	75.6	82.6	78.4	87.7	69.1	67.6	67.1	74.9	82.7	84.7
Mean equivalent angle	61.89	62.25	56.79	59.20	60.40	65.35	62.31	69.47	56.20	55.33	55.01	59.92	65.44	66.96
Differences for significance at: 5% = 17.34														

*Fruit grading. Apples in Fancy grade may have up to 15 % of surface area covered by smooth russet. but no rough russet, and they must have at least 15% of surface area covered by typical red colour of Jonathan.

NOTES:—The following insecticides were applied to all treatments: 4 applications of lead arsenate, 1.5 lb., and 3 lb. of hydrated lime, and two applications of 0.25 lb. parathion throughout the season.
Foliage damage did not occur in measurable amounts under any treatment.

TABLE 7. SUBSTITUTION OF ORGANIC FUNGICIDES FOR THE STANDARD LIME SULPHUR/SULPHUR PROGRAMME DURING FLOWERING ON CRIMSON COX, STURMER AND DOUGHERTY, HASTINGS, 1950/51 (3 Trees per Treatment under (a-f) and 2 under (g) with Dougherty; 3 Trees per Treatment under (a-g) and 5 under (h) and (i) with Sturmer)

Application Time	Treatments								
	a	b	c	d	e	f	g	h	i
Green tip, 21/9/50	Bordeaux 10/8/100	Bordeaux 10/8/100	Bordeaux 10/8/100	Bordeaux 10/8/100	Bordeaux 10/8/100	Bordeaux 10/8/100	Bordeaux 10/8/100	Bordeaux 10/8/100	Bordeaux 10/8/100
Open cluster-pink, 7-10/10/50	Venturicide 1.5 lb.	Venturicide 3 lb.	Puratized 0.75 pt.	Ascospray 1.5 lb.	Ascospray 3 lb.	Lime sulphur 0.7 gal.	No spray	Lime sulphur 0.7 gal.	Lime sulphur 0.7 gal.
Petal-fall, 25-26/10/50 and again 8-9/11/50	,,	,,	,,	,,	,,	Lime sulphur 0.5 gal. + Colsul 40 2 lb.	,,	Thirospray 2 lb.	Fermspray 2 lb.
24-27/11/50	,,	,,*	,,	,,	,,*	Colsul 40 4 lb.	,,	,,	,,
11-12/12/50	Colsul 40 2 lb.	Colsul 40 2 lb.	Colsul 40 2 lb.	Colsul 40 2 lb.	Colsul 40 2 lb.	Colsul 40 2 lb.	,,	,,	Fermspray 1.5 lb.
27-29/12/50 and 15-16/1/51	,,	,,	,,	,,	,,	,,	,,	Colsul 40 4 lb.	Colsul 40 4 lb.
2/2/51 (h, i), 12/2/51 (a-g)	Bordeaux 1/4/100	Bordeaux 1/4/100	Bordeaux 1/4/100	Bordeaux 1/4/100	Bordeaux 1/4/100	Bordeaux 1/4/100	,,	Colsul 40 2 lb.	Colsul 40 2 lb.
Dougherty:									
% fruit infection	6.0	2.2	3.0	4.0	1.3	0.1	46.3		
Mean equivalent angle	14.2	8.5	10.0	11.5	6.5	1.6	42.9	Treatments not used on Dougherty	
Differences for significance at 5%:		amongst (a-f) = 8.1;		(a-f) versus (g) = 9.1					
1%:		,, ,, = 11.4;		,, ,, ,, = 12.8					

% Fancy fruit (russet grading)**	70.2	51.1	72.1	64.3	73.3	67.9	86.8		
Mean equivalent angle	56.9	45.6	58.1	53.3	58.9	55.5	68.7		
Differences for significance at 5%:		amongst (a-f) = 10.3;		(a-f) versus (g) = 11.6					"
1%:		" " = 14.6;		" " " = 16.3					
Sturmer:									
% fruit infection	0.3	0.0	0.1	0.0	0.1	0.0	4.8	0.5	1.5
Mean equivalent angle	3.0	0.0	1.8	0.0	1.7	0.0	12.6	4.2	6.9
Differences for significance at 5%:		amongst (a-g) = 7.4;		between (h, i) = 5.7;		(a-g) versus (h, i) = 6.6			
1%:		" " = 10.1;		" " = 7.8;		" " " = 9.0			
% Fancy fruit (russet grading)**	73.5	35.4	44.3	57.3	45.8	59.4	89.4	70.5	56.8
Mean equivalent angle	59.0	36.5	41.7	49.2	42.6	50.4	71.0	57.1	48.9
Differences for significance at 5%:		amongst (a-g) = 12.2;		between (h, i) = 9.4;		(a-g) versus (h, i) = 10.9			
1%:		" " = 16.5;		" " = 12.7;		" " " = 14.8			

*In spraying Crimson Cox owing to severe defoliation Colsul 40, 2 lb., was substituted for the organic mercury fungicides in Treatments (b) and (e) on November 24.

**Russet grading details: on Dougherty, Fancy allowed maximum of 10% smooth russet.
on Sturmer, Fancy allowed maximum of 60% smooth russet.

NOTES:—The following insecticides were applied to all treatments: Selocide 1 pt. at petal-fall; lead arsenate 1.5 lb. and hydrated lime 3 lb. in 4 applications up to early January followed by DDT 0.25 lb. p.p.i. in 3 applications.

(a) On Crimson Cox a light crop with severe rough russet on all trees made fruit records valueless. On this variety leaf damage was an important feature of the trial. Damage first became noticeable after the Petal-fall applications, and by November 21 trees having Treatments (b) and (e) had suffered approximately 50% defoliation while leaves remaining were burnt in spots. Trees under Treatments (a), (c) and (d) and some leaf-drop and light spray burning, while with Treatment (f) there was some leaf-drop without burning.

(b) On Dougherty, fruit russet was nearly all of the smooth type, largely restricted to areas round the calyx and stalk, and would not exclude the apples from export grade. When fruit of this variety was graded for colour, it was found that Treatment (e) alone reduced colour by an amount significant at 5% when compared with colour of unsprayed fruit. On Dougherty a slight amount of leaf-drop occured amongst the first leaves with Treatments (b) and (e): otherwise foliage was good.

(c) On Sturmer, leaf damage began after the Petal-fall applications of Treatments (a)-(e), and by November 21 spray burn and leaf-drop had become marked. By this time trees under Treatments (b), (c) and (e) had become damaged beyond acceptable limits.

BOOK REVIEW

THE TRICHOPTERA (CADDIS-FLIES) OF AUSTRALIA AND NEW ZEALAND

By Martin E. Mosley and D. E. Kimmins. British Museum (Natural History) 1953. 550 pp. £4 10s. 0d.

In this work the authors have aimed at providing as complete an account as possible of the caddis-flies known to occur in Australia (including Tasmania) and New Zealand. Many of the types of these insects are held in the British Museum, e.g., those described by McLachlan and Walker and furthermore many of the types of the species collected by Tillyard and Hudson, so that these are unavailable to the entomologist working in Australia or New Zealand. Types of other species are held in such institutions as Harvard College, U.S.A., and the Stockholm Museum. The authors have produced a work that gives an excellent systematic account of all species described by others and also of those that they themselves describe; in cases where it has not been possible to examine specimens the original describer's remarks are reproduced. In effect the work is a complete reference to the Australian and New Zealand faunas of the order and is of invaluable assistance to workers in those countries.

The book begins with an introductory portion which gives the history of the work and in this it is stated that one of the authors (M. E. Mosely) died before the completion of the project and the part each author played in the preparation of the text is set out by D. E. Kimmins. There follows a section on the scope of the work and discussion of the fauna. Here it is stated that the boundaries adopted for the work are the Australian Continent, the island of Tasmania, and the North and South Islands of New Zealand. Before this book appeared, 55 species of Trichoptera were recorded from New Zealand and approximately 40 described species from Australia. The authors' work brings the total for New Zealand to 76 species in 33 genera and to 177 species in 69 genera for Australia. It is stated that for Australia, at least, this is a ridiculously low total for the size of the continent and that systematic collecting is sure to bring to notice many more species. It is interesting to note that the dominant family in the Trichoptera in Australia is the Leptoceridae, whereas in New Zealand first place is taken by the Rhyacophilidae. To complete the introduction there follow sections on structure, life-history and habits, enemies of Trichoptera, and on collection and preservation.

Almost all of the remainder and by far the greater part of the book (508 pp.) is taken up with a systematic account of the families, genera and species. In the description of species a feature is the importance given to the genitalia and considerable space is devoted to this aspect. The keys are excellent, being for the most part simple and short. Descriptions too appear to have been very carefully drawn up and should provide ample material for differentiating between species. The authors have not hesitated to quote descriptions drawn from other works. This must be done of course where no material was available for examination and in many other cases original descriptions have been quoted and amplified where material was available. In this type of work the whole effect is entirely good, as the authors have aimed to produce a volume that gives a complete account of the order in the countries concerned. Mention must be made of the excellent drawings which are the work of D. E. Kimmins. These are carefully and attractively done and generally add to the obviously high standard of the publication. At the end of the work there is a check list of Trichoptera recorded

from Australia, Tasmania and New Zealand, and an appendix of 13 pages in which A. G. McFarlane's descriptions and figures of 11 species of New Zealand Rhyacophilidae are reproduced; the whole concludes with an index.

This book ranks among the very best that have been published on the insects of New Zealand, Australia or Tasmania. It is clearly a very excellent scientific account of the order and it exhibits the quality of its scientific standard and workmanship on every page. To the worker in Trichoptera the book is, of course, indispensible.

One small matter noticed by the reviewer is that in a few cases the place of deposition of the type is not stated. One hesitates to bring up a comparatively small thing like this where the standard of excellence is so high, but in a complete reference work it is considered such information is worth inclusion.

W. COTTIER.

PUBLICATIONS RECEIVED

Proceedings of the Bihar Academy of Agricultural Sciences. Vols. II and III. 1953-54. 156 pp.

This official publication of Bihar Academy is in future to be issued annually. A number of the eleven papers should be of interest to Agricultural Research workers in New Zealand. It includes articles on Improvement of Soil Fertility by the Application of Heat, New Systems for the Maintenance of Soil Fertility and the Effects of Insecticides on Aphids and their Parasites and Predators.

The Journal of Soil Science. Vol. 5 No. 1. Jan. 1954. Oxford at Clarendon Press. 172 pp.

This issue of the Journal of Soil Science maintains the high standard set in the previous volumes. It includes a series of three articles on Podzolisation and articles on Release of Silicia from Soils by the Orthophosphate Anion, Soil Structure in Relation to Soil Suction and Isotropic Equilibria between Phosphates in Soil.

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